

The Blast Furnace *and* Steel Plant

The Iron and Steel Industry of Australia

Location of the Iron Ore Deposits—Some Early Industries—Steel Works of the Broken Hill Proprietary Company, Ltd., At New Castle, N. S. W.

By R. A. FIELD.

Modern industrial progress has been dominated by the successful exploitation of the world's mineral resources, especially coal and iron. Although Australia has produced a negligible quantity of iron and steel, she possesses some rich and very extensive deposits of iron ore and coal; but the mere fact that these deposits are so far removed from suitable centers of supplies and the means of communication so limited, explains why until recently very little has been done in the way of converting these deposits into a marketable commodity.

Coal was discovered at a very early period in the history of the country; the first mention of it dating back to the year 1797 when its existence on the south coast of New South Wales was noted by the survivors from the wreck of a sailing ship. According to the estimate made by the International Geographical Congress, Australia has 165,572 millions tons of coal reserves. Prior to the war Australia produced about 12,000,000 tons of coal per year, of which 10,000,000 tons came from New South Wales alone. A great amount of this coal is exported; about fifty per cent of the output being exported either in bulk or as bunker coal.

Distribution of Iron Ore Deposits.

New South Wales:—According to the report of the Government Geologist, the total amount of ore available in New South Wales is 53,000,000 tons. The rich deposits of Cadia are computed at 39,000,000 tons, the aluminous ores at Wingello are estimated at 3,000,000 tons; the titaniferous magnetic ores on the Karuah River at nearly 2,000,000 tons, and the hematite and brown ores at Carcoar at 3,000,000 tons, while several other districts are capable of supplying over 1,000,000 tons.

Queensland:—In the northern state, the ore is mined chiefly for fluxing purposes in connection with the reduction of copper and other ores. About 50,000 tons of iron ore are mined per year at Iron Island and used as fluxes at the Mount Morgan mine near Rockhampton.

South Australia:—The best known and largest de-

posits in this State are at Iron Knob and Iron Monarch. These are veritable hills of iron and it is estimated that there are 21,000,000 tons of hematite ore in sight. This property has been leased by the Broken Hill Proprietary Company, Ltd., and until two years ago the ore was used exclusively as a flux in their lead smelters at Port Pirie. Extensive beds of limonite with a little hematite are found at Cutana, and at Mount Jagged where a small quantity of pig iron was made about thirty-five years ago, some deposits of hematite are found.

Victoria:—Iron ore has been located at various places in Victoria particularly at Nowa Nowa and at Dookie, but at present there does not seem to be any prospects of these deposits being worked.

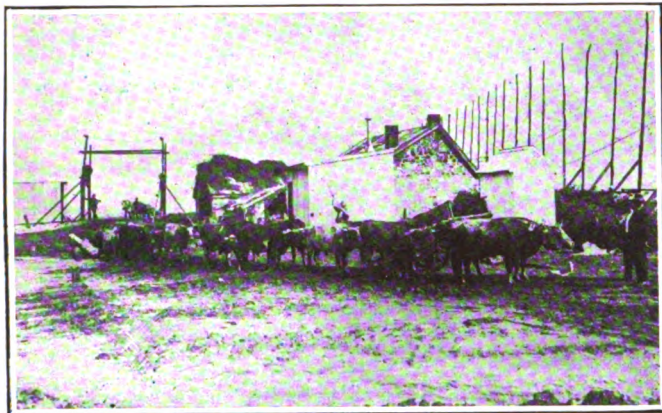
Western Australia:—Owing to their isolation, the most extensive fields in this state are at present unexploited. The production of the state is confined chiefly to the ore needed for fluxing purposes.

Tasmania:—The existence of large quantities of iron ore in Tasmania was made known by the Surveyor General as far back as 1822. In 1876 a company known as the Tasmanian Charcoal Iron Company was formed to work the deposits near Launceston. Unfortunately however, the presence of chromium rendered the pig iron so hard and brittle that the work was abandoned. Some large deposits of specular iron ore are found near the Blythe and Gawler Rivers.

Early Industries.

Ironworks were established at Fitzroy, near Mittagong in New South Wales, as early as 1852, and at Lithgow (Eskbank) in 1875, but in neither case was very much produced. In May, 1907, works on a much larger scale were opened at Lithgow, by G. Sanford, and in January, 1908, they were taken over by the firm of G. & C. Hoskins, Ltd. Work was interrupted for some weeks in 1908, owing to a labor dispute, and during this time the opportunity was taken to make considerable alterations to the plant in order to increase the output. The iron ore used is obtained at Carcoar, and is smelted with local coal converted into coke in 100

beehive ovens. At present the plant consists of two hand-filled blast furnaces of a combined weekly output of 2400 tons of pig iron; two basic open hearth furnaces, one of 60 tons and one of 30 tons capacity, 17 puddle furnaces; a 28-in. blooming mill; a rail mill, and a sheet mill. Most of the pig iron produced is for



Bullock team bringing piles for construction of steel works, May, 1914, New Castle, N. S. W.

foundry purposes or for puddling, as only about 4000 tons of steel ingots are produced per year.

Governmental Encouragement.

In order to encourage the development of the iron ore deposits and the converting of the same into iron and steel, the Commonwealth Government passed the "Manufacturers' Encouragement Act" which came into force January 1st, 1909, and expired June 30th, 1912. This act provided for the payment of a bounty of a total of £150,000 (not to exceed £30,000 per annum) on all pig iron, puddled iron or steel made from Australian ore; also a total of £30,000 for sheets, wire and pipe. This bounty was to be paid at the rate of twelve shillings per ton on all pig iron, puddled iron and steel, and 10 per cent on value of wire and pipe produced. For the year 1910 bounties to the extent of £32,578 were paid on the above products.

The Steel Works at Newcastle, N. S. W.

The first step which led to the establishment of the Steel Works at Newcastle, was the leasing, by the Broken Hill Proprietary Company, Ltd., in 1889, of the Iron Knob and Iron Monarch deposits about thirty miles inland from the west side of Spencer Gulf in South Australia. These deposits contain very rich hematite and also some manganese ore. The following analyses show the ore to be very constant, both in iron content and gangue:—

Sample	Date taken	SiO ₂	Fe	Mn	H ₂ O	P
Iron ore, July 12, 1915....	3.2	65.	.50	1.83	.041	
Iron ore, July 31, 1915....	4.08	63.6	.49	2.74	.045	
Iron ore, Aug. 27, 1915....	3.00	65.8	.66	1.98	.050	
Iron ore, Sept. 27, 1915....	2.20	65.4	.62	1.50	.048	
Iron ore, Oct. 19, 1915....	3.70	64.6	.50	2.50	.048	
Mang. ore, Aug. 12, 1915....	1.78	53.4	10.08	2.90	.050	
Mang. ore, Aug. 12, 1915....	1.14	54.4	11.80	2.80	.049	

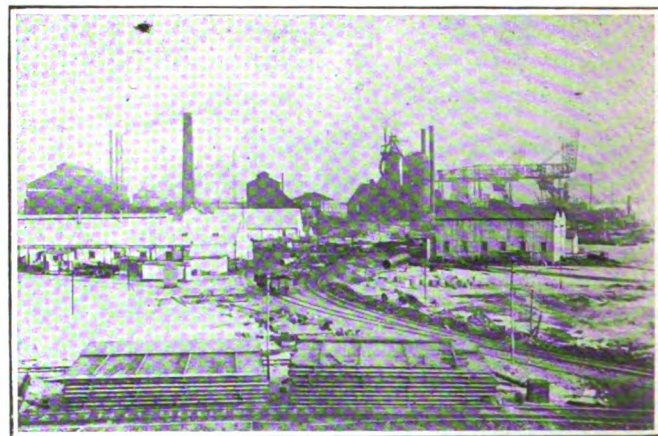
The object of the company in securing this deposit

was to provide itself with iron ore to be used as a flux in their lead smelting plant at Port Pirie, and after using 800,000 tons of ore in this way and being satisfied that the supply of ore would warrant it, the directors decided to utilize the deposit in the manufacture of iron and steel. Accordingly in 1911, Mr. G. D. Delprat, the General Manager of the company, was sent abroad to make the necessary investigations. He visited the leading steel works in England, Germany and America, and as America appeared to possess the most modern appliances it was decided to obtain the necessary equipment from there. While in America Mr. Delprat secured the services of Mr. David Baker, consulting engineer, who designed and constructed the plant, and is now managing its operation.

Since it is cheaper to transport the ore than the fuel, a site was sought near the Newcastle coalfields, and by the aid of the Government of New South Wales, the present site at Port Waratah was acquired with its excellent wharfing accommodations.

In spite of the disturbing influences of the war, only two years were required to construct the plant. The first installment of machinery from America was discharged January 3, 1914, and the blast furnace blown in March, 8, 1915. The first heat was tapped April, 9, 1915, and the first rail rolled April 17, 1915. The cost to complete the works and develop the resources of ore and limestone was £1,500,000 of which £88,000 were paid as duty on imported machinery and equipment.

Raw Materials:—The ore which is a hard red hematite, is mined in an exceedingly dry district and as delivered at the blast furnace seldom averages over 3 per cent moisture. It is brought from the mines which are thirty five miles inland, to Hummock Point by railway



View of steel works, September, 1915, New Castle, N. S. W.

and is then crushed and placed in bins from which it is fed into the hold of the steamer by means of an endless belt at the rate of 800 tons an hour. At the blast furnace stockyard the steamer is discharged by two Hoover and Mason ore bridges.

The Coal is obtained from the Newcastle coalfield

and converted into coke in By-Product Ovens. Lime-stone for flux is obtained from Melrose quarries in Tasmania, which are leased by the company, and is delivered to the blast furnace by steamer.

The Coke Oven plant consists of 66 Semet Solvay Recuperative By-Product Ovens, producing about 5 tons of coke per oven. The sulphate and tar are extracted and sold as by-products while the gas is used in the mills. Sixty-six more ovens of the same type are in the process of construction and will be completed in a short time. The coke is pushed on to a platform from which it is forked into small trucks which contain exactly one skip of coke each. These trucks are taken from the ovens by a narrow gauge locomotive, run into the blast furnace stock house and dumped directly into the skip. The Newcastle coals produce a coke which is rather friable and by this means of handling, the loss in breakage is reduced to a minimum.

At present there is one modern skip-filled blast furnace, 85 feet high, 13 feet hearth, 20 feet bosh, equipped with a Baker-Neuman top and producing 400 to 450 tons of basic pig iron per day.

Space is provided for five additional furnaces to be added as fast as business conditions will permit, the second furnace being under construction at the present time. Four side combustion Cowper Stoves 908 x 21-ft. are provided for heating the blast which is furnished by three Mesta steam driven blowing engines with air cylinders 84-in. x 60-in. A Steece & Ford gas washer

is used to wash the gas and five batteries of B. & W. gas fired boilers furnish the steam. The pig iron is tapped into 45 ton ladles and taken to the mixer or run over the two strand Heyl and Patterson pig machine. The slag is either granulated or tipped while molten depending upon the materials wanted for filling purposes.

The steel plant consists of seven 65 ton stationary basic open hearth furnaces, using producer gas for fuel, and a 1000 ton gas fired metal mixer to store molten pig iron.

The Mills comprise the following:—A 35-in. two high blooming mill with 3 four hole soaking pits, a 28-in. three high rail and structural mill with two reheating furnaces, for rolling rails, standard shapes, and munition steel; and an 18" mill with continuous reheating furnace for rolling light shapes, billets, and sheet bars; and a 12-in. and an 8-in. mill are now under construction. A continuous Morgan rod mill has also been purchased by the company.

Australia imports 500,000 tons of steel per annum and as there is a determination on the part of the people and the government to encourage home industries and to manufacture all the country's requirements inside the Commonwealth, the outlook for the future of the industry is bright in spite of the fact that wages are high and labor troubles frequent. At the present time this country is exporting to Great Britain 50 per cent of its steel production.

Causes of Steel Ingot Defects

Defects Classified as Pipes, Segregation, Occluded Slag, Fluxed Fire Clay, Lappiness, and Cracks—Advantages of Various Types of Molds and Methods of Pouring.

By J. N. KILBY, Sheffield.*

A good percentage of the defects in steel ingots come under the following heads:

Pipe, Segregation.

"Occluded slag."

Fluxed fireclay (occluded).

"Lappiness."

Cracks.

Pipe.—A given volume of similar liquid steel will, under like conditions, solidify with a definite amount of or volume of, shrinkage.

The receptacle into which the steel is cast governs the position in the ingot of the pipe cavities, and therefore the amount of the ingot which it is necessary to discard for the production of sound steel.

Fluctuations in casting temperature, rate and method

of teeming, percentages of silicon, manganese, and aluminium influence the pipe more or less according to the type of moulds used.

Steel makers, after thorough investigation, must accept the mould with the wide end up as the one conducive to minimum pipe. The longer the ingot in proportion to its cross-sectional area the worse the trouble with the old narrow end up type, (see Fig. 2). Mould type, and method of casting, should be made one of the most important points of steel specification.

The use of the old type mould, Fig. 1, A is still part of the standard practice in a good many works. It would be interesting to have some discussion upon this point, obtaining the views of those who adhere to this class of mould. With the exception of giving the pitmen and cranemen a fairly easy time there does not appear a single point in its favour. One of the greatest objections to the "new mould" in its earlier days was

* Abstract of paper read at annual meeting of the British Iron and Steel Institute meeting, May 4, 1917.

based upon the fact of its causing exceptionally heavy and more exacting pit work.

After the question of mould type, one has to consider the necessity of using a feeder head and type of the same.

Except with special steels, the use of a refractory feeder head has not been widely adopted. That it is necessary to produce the maximum of sound steel is beyond dispute. The type of feeder head does not matter a great deal, inasmuch as reducing pipe is concerned, provided it is of sufficient capacity adequately to feed the chill portion.

Setting aside the question as to whether these defects are in any way detrimental to these particular classes of steel or not, there remains the fact of cost of production, which appears to be the real basis for not using heads more generally, or in other words, the extra cost incurred by the use of a feeder head would not be more

We have therefore an increased yield of 10 per cent for the cost of the feeder head, not considering the 15 per cent doubtful material used as sound.

Apart from the increased yield and more reliable steel, there is the great saving in the ultimate manipulation of the ingot in the rolling-mills, etc.

It would appear therefore that feeder heads are economically essential even for what is termed the "ordinary" steels.

Occluded Slag. Acid Open Hearth.—Any oxide of iron admixed in steel exerts itself to a great degree upon the silicon and manganese additions just prior to tapping, and the aluminium after tapping, forming particles of "slag." Whether these particles remain evenly disseminated throughout the mass, or whether they partly or wholly collect and rise to the surface in the slag, is a matter governed by circumstances, and overshadowed by a good deal of doubt. As is well known,

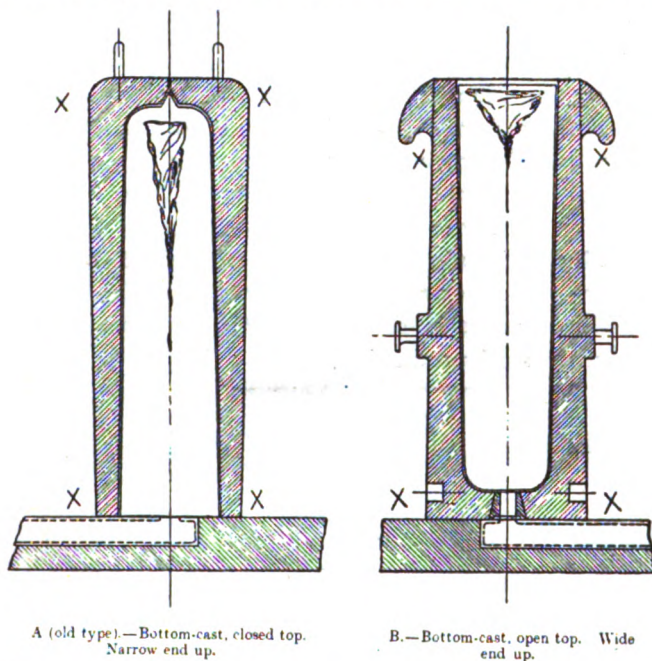


Fig. 1.—Showing relative thickness of mould at top and bottom and comparative "XXXX" influences upon solidification.

than covered by the saving of steel. Let us see whether this is so or not.

The cost of production turns upon how much of the piped portion of the "unfed" ingot is utilized as saleable steel, against the cost of the feeder head and its gain in yield. The cost of a feeder head per ton of steel varies greatly according to size of ingot and also according to type of head used.

The figures and details below are from actual works costs, and based upon piping steels of 0.45 per cent carbon.

Ingot without Feeder Head.	
Yields	65 per cent sound
Yields	15 per cent doubtful
Yields	20 per cent scrap.
Ingot with Feeder Head.	
Yields	90 per cent sound steel.
Yields	10 per cent scrap.

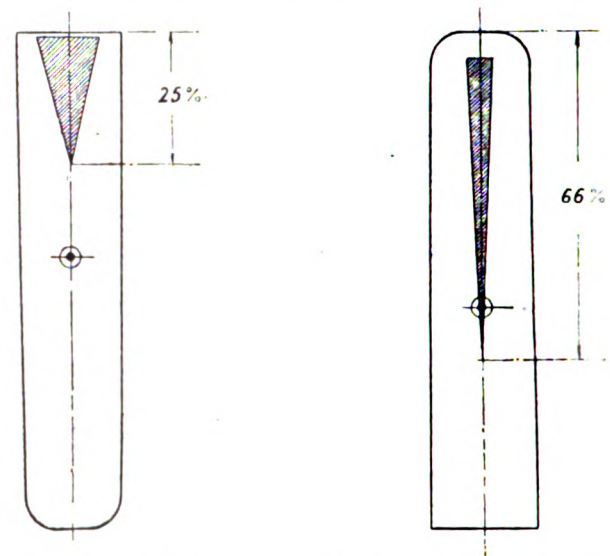


Fig. 2.—The center of volume in two ingots same size of both types, also the position of the pipe cavities given as equal, and based upon actual ingots, showing amount of ingot susceptible to pipe cavities.

alloy steels and special carbon steels will not give maximum physical tests if not "free" from such admixture. The author is referring to steel which was supposed to have been "well melted" and worked throughout and given correct finishing conditions. The presence in ordinary carbon steels of this finely divided or emulsified solution of slag is just as little desired as in the case of special steels, although not so liable to influence the ordinary physical tests called for in these steels. The author contends there are two sources whereby "oxides" may be taken and retained in the steel, viz.:

- 1.—That formed during melting of the charge and not subsequently removed.
- 2.—That introduced by excessive or erratic feeding of ore.

In the author's opinion the first essential in acid open hearth manufacture should be the one of correct

and consistent conditions at the melted stage. A good deal of importance is rightly placed upon the finishing conditions of the steel, and as these conditions are in sequence to the conditions at melting, and to a great

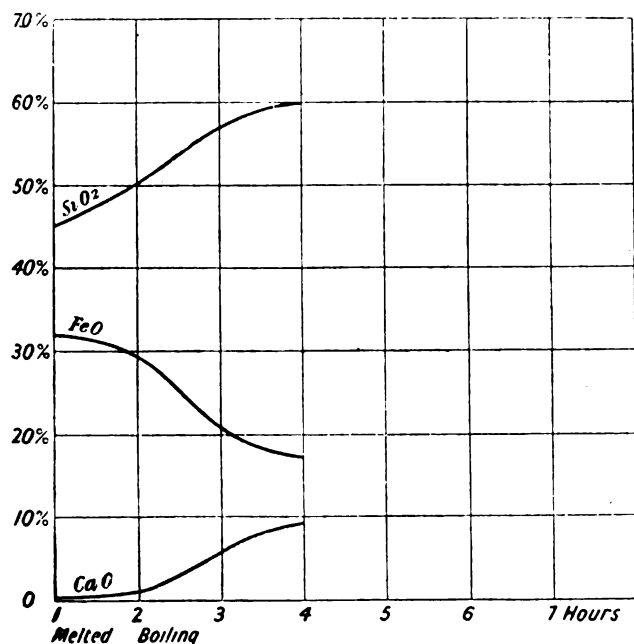


Fig. 3.—Chart I.

extent governed by the latter, too much stress cannot be laid upon early stages of the heat.

A charge going to boil by virtue of the oxide formed during the melting down stage is, to say the least, not conducive to yielding a steel anything free of oxides and slag inclusions. No matter what subsequent method of deoxidation be resorted to, the author contends there is great danger of a significant residual portion. A furnace working badly, such as at the end of a campaign where a record run may be being sought after, gives just that state of bath referred to. Slowly and cold melted charges are always highly charged with oxide. In these days of increased output and pressure upon furnace conditions and the usage of large proportions of the poorer grades of scrap, the presence of the evil is more likely to crop up than where output is of secondary importance given other conditions as equal.

The working of many and particular brands of iron in one charge had its basis of advantage unconsciously built upon silicon content, yielding regular and nearly accurate bath conditions at melting.

The two important factors up to the "melted" stage are:

- 1.—Quick melting.
- 2.—Correct state of slag and bath at melting.

The author has found that a 2.00 per cent silicon basis is a good one to work to. By this is meant that the whole charge should have an available silicon content of 2.00 per cent, taking the silicon in the pig iron, and making the difference up by adding slag in with the charge; for example:

50-ton Charge.
 20 tons pig iron..... 1.90 per cent silicon,
 30 tons scrap..... 0.10 per cent silicon,
 =0.80 per cent silicon average,

which requires 1.20 per cent silicon, adding in the form of slag, which works out at approximately 43 cwt. The use of slag in the charge reduces the amount of oxidation greatly, and gives more reliable bath conditions.

The melting of the charge is a strongly oxidizing period, and, as previously stated, the question of what becomes of the whole of such oxide formed is a highly important one. It may be argued chemically that: "Any oxide formed must naturally be reduced by carbon, silicon, and manganese in the pig iron, in contact with which the reaction would appear inevitable."

Granted, that if the correct excess of these elements was available and the conditions were suitable, the re-

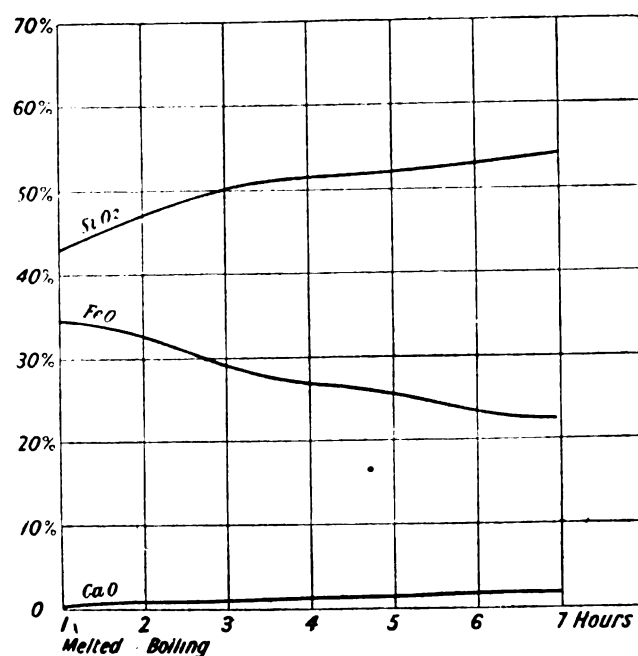


Fig. 4.—Chart II.

action as stated above would probably occur, but an acid charge in reaching the melted condition does not exhibit much sign of either violent or a milder reaction, nor does it give the impression of freeing itself energetically

from oxide. It is fair to assume that, the higher the carbon and the greater the "residual" silicon at melting, the less the opportunity for oxide retention, also that charges requiring little or no ore to work them must be in a highly receptive state for oxide.

It is well understood that the furnace banks and bottom suffer most after heats taking little ore. One can explain why only that part of the banks which is in

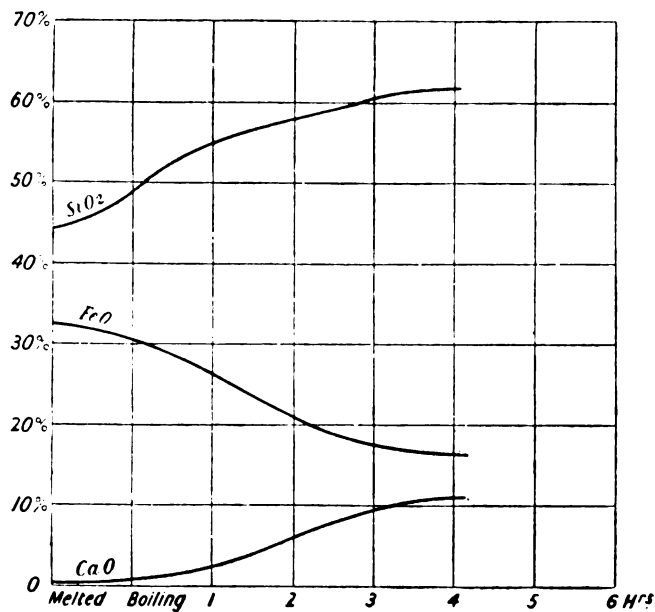


Fig. 5.—Chart III.

immediate contact with the slag should be "cut" or fluxed away, but this explanation does not apply to the wear of the bottom. May it not be, under certain conditions of slag bath and temperature, that the metal holding these aforementioned oxides of iron is continually feeding upon the furnace hearth and producing particles of "slag," and the subsequent working is only partially removing the "slag," thus formed.

Effects of Limestone. Acid Open Hearth.—The use of limestone in the acid open hearth process is one of the greatest importance, as also the period at which additions should be done.

Charts I., II., III., and IV. (Figs. 3 to 6) give some idea of the influence of limestone upon the chemical composition of the slag. They are taken from a number of heats and are typical of CaO effect.

A highly siliceous slag low in FeO may be obtained quickly after boiling. A slag of "finishing condition" is formed soon after the charge has gone to boil by correct addition of lime-stone. If it is advantageous to work with a slag of a highly siliceous character towards the end of the boil, surely the earlier stages would be benefited by such similar conditions. The rate of fall in carbon is more regular and consistent with good results. Although the slag is apparently more mobile it merely indicates in these circumstances a perfect state of flux and correct reaction. The question of the effect of limestone is introduced in order to raise the point of its action upon occluded "slag" in the bath.

The nature of the acid hearth is one of silica and silicates of iron mostly. The slag of the process is also silicates of iron and manganese, so is the nature of any occluded particles. The hearth when new is in a highly receptive state, and absorbs a large quantity of the oxides formed during melting. After a few heats, however, this absorption ceases. The melter usually remarks upon the first few heats regarding the "boil." The reaction and appearance do seem a little perplexing, and certainly different when the hearth has satisfied itself.

Under normal conditions therefore we have in this process a bottom, and slag of a similar composition to the occluded matter. Without the addition of CaO the slag runs about 50 per cent silica, but with correct CaO addition it may reach 62 per cent. It may be argued that a slag capable of retaining 60 per cent SiO₂, and being in a fairly mobile condition, would more readily absorb from the bath any suspended particles of "slag" than one low in SiO₂ and comparatively high in FeO.

Lappiness in Ingots.—Bottom-cast steel poured at too low a temperature or to slow a speed tends to cause "lappiness" or "folds" in the ingot. Ordinary carbon steels of course do not suffer much from this condition, since if the steel is so cool as to "lap" badly, the chances are much against the ingots filling. Chrome steels and high silicon steels (the latter up to 2.50 per cent silicon) are almost always apt to subject themselves to lapping

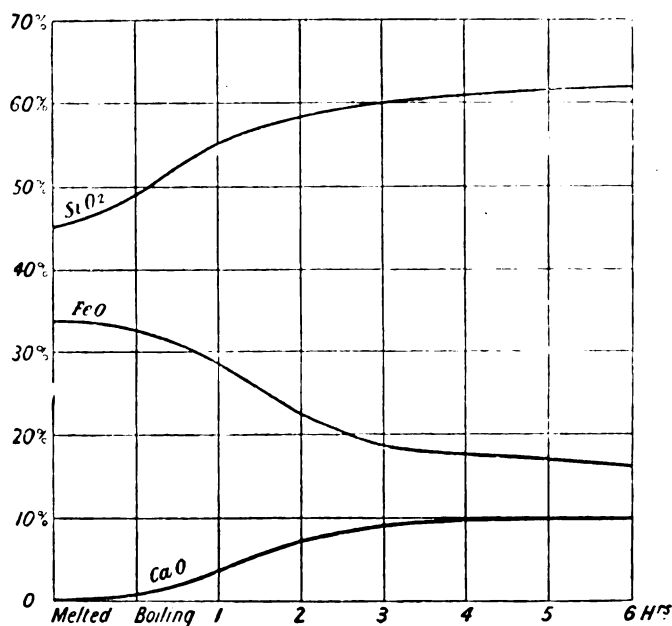


Fig. 6.—Chart IV.

in a more or less degree. The appearance of the ingot may give some idea as to whether the lapping is going to be a serious defect or not, but on the whole it is a matter for further investigation. It is thought by some steelmakers that the lapped portion of the steel becomes coated with a film of oxide, which is embedded in the ingot by the flow of steel over it; also, that this forms

the beginning of a flaw in the rolled bar, taking the form of a crack or split, after the bar has been subject to pickling. The author is of the opinion that any cavity or split in a rolled or forged bar has no relationship whatever with lapping in the ingot. This opinion is based upon a number of nickel chrome and chrome ingots, carefully watched throughout their making, and on a careful comparison of the cost of chipping out of flaws (nine in each cast separately) in the finished bars. Some of the best casts appeared to be the worst as regards laps, and summing up one could not say that the lapping was serious as would be supposed. The use of comparatively large nozzles in the ladle, and a small number of ingots per bed, lead to what the author terms spasmodic teeming, the stream from the ladle running at full force being of greater volume than is compatible with correct filling of the moulds. The teemer has then to use his discretion and endeavour to control the stream to fill the moulds correctly. What is obtained

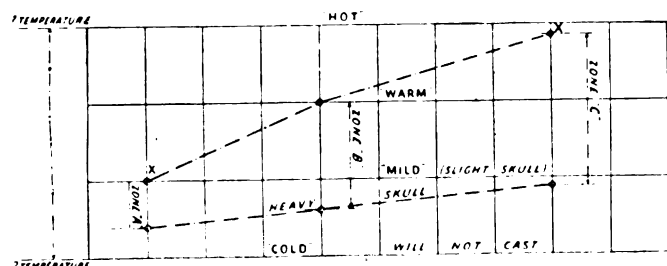


Fig. 7.—Chart V. Casting chart (bottom-cast steel). Dealing with "casting temperature." To show comparative safety ratios to cast ingots without cracks. Zone "A".—Where the ladle running at full stream is above the capacity of the ingots on the bed, and the rate of filling rests entirely with the control of the stopper by the teemer. Zone "B".—Where the number of ingots per bed is just under the capacity of the ladle, casting at full stream. Zone "C".—Where the nozzle size and the capacity of the bed balance when casting full stream, the steel tending to freeze slightly on the surface during filling. Above the line "XX" cracked ingots prevail.

is an ingot teemed at various speeds and in a good many places; the stream being momentarily cut off, one would expect trouble from such teeming, which may wrongly be put down to the steel having a habit of lapping.

Fluxed Runner Bricks, etc.—In bottom-cast steel the flow of the metal in contact with the fireclay trumpet pipe and runner bricks causes an erosion, the product of which is carried along into the ingot. The extent to which the erosion is carried depends mainly upon the composition of the steel and the casting temperature. It is more or less common to all bottom-cast steel.

Low carbon steel attacks the fireclay material much more readily than the higher carbon steels. Axle and low carbon forging material, which have to be machined and closely inspected, are much subject to rejections owing to the occlusions being rendered visible. Ordinary billet material, although suffering from the same evil, may escape severe notice; moreover a sandy billet may be thrown out here and there without serious loss or raising comment, the yield not being so greatly affected as where the defect shows a large article.

The author contends that all bottom-poured steel is subject to occluded fluxed runner bricks, and that it is present in the ingot in various positions, but principally from the skin to a depth of a few inches. The tendency for this "slag" on entering the mould is to rise to the surface and towards the sides of the ingot, the flow of the steel carrying it to its final position. Seeing that the steel in the immediate vicinity of the mould begins to solidify on contact, the fluxed runner brick has little opportunity to reach the actual face of the ingot and

TABLE I.—Teeming Speeds. Record of a Number of Various Size Top-poured Ingots Free from Cracks.

Weight.	Section.	Time of Teeming.
15 cwt	12 inches square	2 minutes.
25 ..	14	2½ ..
50 ..	20	6½ ..
60 ..	22	6 ..
80 ..	24 .. octagonal	8 ..
100 ..	28	9 ..
12 tons	36	18 ..
20 ..	40	25 ..

TABLE II.—Teeming Speeds.

40 tons capacity cast, 0.45 per cent. carbon steel. Ingots 50 cwt., 20 inches square (50 casts).

Time in Minutes.	Ingots Cracked at Mill.	Bars to Chip due to Cracks.
2	All badly	Nearly all
3	50 per cent.	40 per cent.
3½	40 ..	30 ..
4	10 ..	8 ..
5	5 .. slightly	4 ..
6	2 .. very slightly	2 ..
7	None	2 ..

1 Tun dished.

TABLE III.—Teeming Speeds (Two Typical Heats).

30-ton heats, 0.45 per cent. carbon steel. "Bottom cast." Ingots 12 inches square.

Nozzle in Ladle, 1 inch (5 cwt. skull).

Bed No.	No. of Ingots per Bed.	Weight per Bed.	Time, Minutes.	Bars to Chip for Cracks.
1	6	90 cwt.	4	None
2	6	90 ..	4	..
3	6	90 ..	3½	..
4	6	90 ..	3½	..
5	6	90 ..	4	..
6	4	60 ..	2	A few
7	2	30 ..	1½	All
Nozzle in Ladle, ½ inch (4 cwt. skull).				
1	6	90 cwt.	5	None
2	6	90 ..	4½	..
3	5	75 ..	3½	..
4	6	90 ..	4½	..
5	6	90 ..	4½	..
6	4	60 ..	3½	..
7	2	30 ..	2	A few slightly
2	top-poured		1	Nearly all

become merely a surface defect. Those whose duty it is to examine bars rolled from ingots having these inclusions know only too well to what depth the defect may run; unfortunately only a proportion is so near the surface as to be observed and chipped out or the material scrapped. Apart from material actually fluxed by the flow of the steel we get the "jointing" (used in the trumpet and runner brick joints) washed off in fairly large pieces, often too large to become fused. The position taken up by these pieces of "dirt" is similar to

that of fluxed runner, etc. Extraneous matter such as fireclay jointing may be largely eliminated by using a suction ejector down each mould and a "trumpet" pipe immediately prior to casting.

Cracks in Ingots. Acid Open Hearth.—There are two positions in which cracks are chiefly experienced in ingots:

- 1.—Cross sectional.
- 2.—Vertical, and principally at the corners of square or octagonal ingots.

Around this subject there rises the point of casting temperature, and teeming speeds. Chart V. (casting details) is to illustrate the comparative margin of safety in casting ingots free from cracks under varying nozzle sizes and capacity per bed. For top poured steel, zone A may be taken for direct poured ingots against zone C for correctly "tun dished" ingots.

The value of pyrometry as a means of controlling furnace or casting temperature is unfortunately very small to the steelmaker and he has to be guided by his experience of the appearance of the furnace, slag, and spoon samples. In nine cases out of ten one cannot talk of hot casts where a skull is left, yet ingots made from such steel will crack in working, and very badly if teemed comparatively quick.

In a number of the works visited by the author the actual teeming times of weight of steel per minute have been little studied, and the reason for cracked ingots has invariably been attributed to heat. The only exceptions to this view have been where speed was thoroughly considered.

Discussion upon hot and mild temperatures in the casting of steel would often lead one to suppose that the actual difference in degrees of heat was extremely great. Granted that it is an easy matter, when once the steel is being cast from the ladle, to say what the temperature is like, it is a different matter accurately to judge from the furnace condition to the fine points necessary.

The human element shows itself very prominently in the open hearth steel trade, and some compromise has to be arrived at which will average all conditions and give the simplest way to success.

The question of size and weight of ingot and weight of steel to be cast are all factors for consideration, as also the use of and the composition of the steel.

Appended are two tables of speed of top-poured ingots and one of typical casts of bottom-poured ingots, showing relative proportions of cracked bars.

Rolling Wide Flanged Beam Sections

Comparative Fibre and Bending Stress Calculations for Bethlehem, Differdingen, Sack and Puppe Sections Assuming Uniform Load Distribution.

By F. DENK.

The additional fibre stresses and the transverse bending stresses, which appear in the flanges by a uniformly distributed load, can easily be calculated by means of the formula

$$M = \frac{p \times l^2}{8} = S_x \times T,$$

where

- M represents the bending moment,
- p represents the load in lbs. per in. of length,
- l represents the length of the free span in in.,
- S_x represents the section modulus,
- T represents the allowable stress in pounds per square inch.

The calculation may be based on a Bethlehem gray section H-8, weighing 34.5 lbs. per sq. ft., with a section modulus of $S_x = 30.4 \text{ inch}^3$. The mean flange thickness is .5 in. The sections to be compared with this one had to be designed with the same thickness, in order to make them comparable with each other.

The different sections in question are shown in Figure 2. "A" is a Differdingen Grey section, having a uniform slope of 9 per cent, while "E" represents a Bethlehem Grey section with a uniform slope of only

2 per cent. To this latter section, as was stated above, the other ones are compared. Figure 2 "B" is a Sack section with entirely parallel flange faces. Figure 2 "C" and "D" illustrate Puppe sections with partly parallel flange faces. Toward the web the inner flange faces are sloped. "C" has a slope of 20 per cent and "D" a slope of 10 per cent.

For the calculation a free span of 8 ft. or 96 in. may be assumed, allowing a tensile strength of 16,000 lbs. per sq. in.

From these data we obtain a safe load of 400 lbs. per running inch, because the bending moment is

$$M = \frac{p \times 96^2}{8} = 486,400 \text{ inch.-lbs., or}$$

$$p = \frac{486,400 \times 8}{9216} = 422 \text{ lbs., say 400 lbs.}$$

Since the flange is 8 in. wide, one square inch is subject to a load of

$$\frac{400}{8} = 50.0 \text{ lbs. per sq. in.}$$

The bending moment for the dangerous point, acting on one running inch of length is for the Bethlehem section Figure 2 "E",

$$M = \frac{50 \times 3.48^2}{2} = 302.8 \text{ inch-lbs.}$$

The section modulus of the flange at the point in question is, again for a length of 1 in.

$$S = \frac{1 \times .538^2}{6} = .048 \text{ in}^3.$$

From this we get the additional fibre stresses

$$K = \frac{302.8}{.048} = 6,310 \text{ lbs. per sq. in.}$$

The Differdingen Grey section, Figure 2 "A", has the same bending moment as given above, i. e., 302.8 inch-lbs. The section modulus is

$$S = \frac{1 \times .657^2}{6} = .072 \text{ in}^3.,$$

and the additional fibre stresses are

$$K = \frac{302.8}{.072} = 4,206 \text{ lbs. per sq. in.}$$

The Sack section again has the same bending moment of 302.8 inch-lbs., (see Figure 2 "B"), a section modulus of

$$S = \frac{1 \times .5^2}{6} = .042 \text{ in}^3.,$$

and an additional fibre stress of

$$K = \frac{302.8}{.042} = 7,210 \text{ lbs. per sq. in.}$$

In the same way it can be shown, that the corresponding figures are for a Puppe section with 10 per cent slope

$$S = .054 \text{ in}^3., \text{ and}$$

$$K = 5,610 \text{ lbs. per sq. in.,}$$

and for a Puppe section with 20 per cent slope

$$S = .067 \text{ in}^3., \text{ and}$$

$$K = 4,520 \text{ lbs. per sq. in.}$$

Tabulating these additional fiber stresses, we get for a

	Lbs. per sq. in.
Bethlehem Grey section	6,310
Differdingen Grey section	4,206
Sack section	7,210
Puppe section with 10 per cent slope	5,610
Puppe section with 20 per cent slope	4,520

This shows, that the highest additional fiber stresses occur in a Sack section; this is only natural, since, in this section, the distance between the dangerous point and the neutral axis is larger than in any other section. The mean thickness of the flanges having been assumed to be the same on all sections under consideration, i. e., .5-in., a Sack section, on account of the entirely parallel flange faces, has this same thickness all over. Since all other sections in question have either a uniform slope (Grey sections) or at least partly sloped flange faces (Puppe sections), the additional fiber stresses in these sections must be smaller than in a Sack section. This is proven by the above calculation.

In the first part of this article (see *The Blast Furnace and Steel Plant*, June, 1917, pp. 271), it was stated, that the Sack section is the one best adapted for making cross connections. This advantage, how-

ever, is offset by the high additional internal stresses, occurring in this type of a beam.

On the other hand, it was stated in last month's issue, that a Differdingen Grey beam was the one least fit for making cross connections, on account of the uniform slope of 9 per cent. But this same slope is the cause for the small amount of additional fiber stresses in this type of beams, being only 4,206 lbs. per sq. in. It is hardly possible to decrease this amount any further, because doing this would mean increasing the slope, and, therefore, making it more difficult to connect cross pieces, plates, angles, etc. This, however, can easily be done on Puppe sections, since increasing the slope on this type, has no influence whatever on the length of the parallel faced

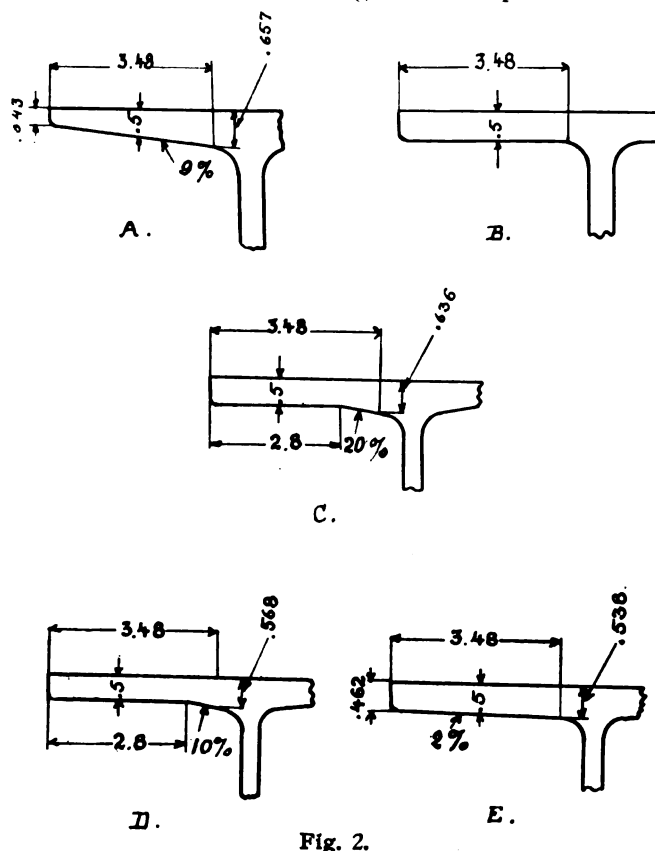


Fig. 2.

part of the flanges. For instance, if this slope would be made 23 per cent, the Puppe section would have the same additional fiber stresses as a Differdingen Grey section, i. e., 4,206 pounds per sq. in. For 25 per cent we would obtain an additional fiber stress of only 4,037 pounds per sq. in.

In the preceding articles the advantages and disadvantages of the different types of wide-flanged beams have been pointed out and explained. All sections under consideration are rolled, as far as they are rolled at all to-day—Sack, Grey and Puppe sections—on universal reversing rolling mills. The sections rolled on three-high mills—Slick type—have not been considered, since they only go up to 10 in. by 10 in., and besides, they are mostly used for mine timbering or similar work and not for heavy construction work.

Sulphur as a Component of Furnace Slag

The Effect of Combined Sulphur on Furnace Driving—Relation to Furnace Gas—Importance in Connection With Lime—Calculations Considering Varying Furnace Conditions.

By WALLACE G. IMHOFF.

Sulphur exists in the blast furnace as combined sulphur, free sulphur, and sublimated sulphur. Combined sulphur is found in the slag as calcium sulphide; free sulphur is uncombined sulphur held as a gas in solution in the slag; sublimated sulphur is heavy yellow deposited sulphur seen in cold slag samples where an excess of sulphur is on the burden such as when high sulphur coke and pyrites ore are on the burden.

The study of sulphur is very important, for it is so closely associated with lime which is the most important of all slag components. The sources of sulphur are in the coke, which at times reaches a high limit of almost 2 per cent; in the ores which with blue billy, pyrites cinder, and others may run as high as 5 per cent; and in very small amounts in the limestone. The following analysis serve to bring out the relation of sulphur in ore, coke and stone.

Coke			
	Low	High	
	Sul. Coke	Sul. Coke	
	Vol. 1.08	Vol. 2.52	
Fixed carbon	88.37	80.45	
Ash	10.55	17.03	
SiO ₂	4.92	.....	
AlO ₃	3.62	.....	
Fe	1.22	.....	
Sulphur	.70	1.73	
Ore			
	Lake Ore	Pyrites Cinder	
Fe	54.90	Fe Dry 61.20	
SiO ₂	10.85	Fe Wet 57.53	
Al ₂ O ₃	2.63	Sulphur 43.8	
P	0.60	.....	
H ₂ O	12.10	.....	
Mn	.50	H ₂ O 6.00	
Stone			
Fe .....	.....	.56	
SiO ₂	4.50	.48	
Al ₂ O ₃	1.90	.....	
P .....	.....	.008	
CaO	.47 to 50.00	53.50	
Ca CO ₃	.88-92.00	95.55	
MgO up to 2 per cent .....	.....	1.28	
MgCO ₃ .....	.....	2.68	
Sulphur trace .....	.....	.052	

In ordinary blast furnaces running on lake ores the sulphur going into the furnace would fall well within the limit of 1½ per cent. On other furnaces, especially merchant furnaces with high sulphur coke and pyrites cinder on the burden, the sulphur may reach 6, or even 8 per cent. This requires very careful handling of the lime, since practically all this sulphur must be carried out in slag. The main avenue of discharge for sulphur is the slag, although small amounts or sometimes no doubt even very large amounts, are carried out with the gases.

Combined sulphur must show up in the complete analysis of slag. Lime sulphide is a dry, pure, white powder which may be seen in any laboratory. As a component of slags this powder seems to be dissolved up in the main body of the slag composed of lime and aluminum silicates. This double combination of lime, first as lime silicate and second as lime sulphide, forms one of the most important problems in handling lime on a blast furnace. It also brings to light the fact that slag analysis should show the percentage of lime sulphide.

To illustrate this point the question may be asked, if a very high percentage of sulphur is carried out by a slag what total amount of stone in the burden is required to flux it? And of conditions of the furnace change and the sulphur left free to go into the iron, how much excess stone will it throw into the burden to overflux the silica? The answer to this question explains the reason why so many furnaces become violently limeset.

Two typical slags with very high combined sulphur are here given, and the above question will be answered in actual figures, which will show the importance of understanding the use of lime and also bear out the importance of recognizing the actual amount of lime carried out as calcium sulphide.

High Combined Sulphur Slag Analysis.		
SiO ₂	32.40	31.64
Al ₂ O ₃	12.03	14.00
Fe ₂ O ₃	1.09	.....
MnO	.37	.....
CaO	47.23	49.36
MgO	3.26	.....
Sulphur	3.35	3.84

Taking the high analysis, which shows 3.84 per cent sulphur, this when combined with lime as Ca S equals 8.64 parts of calcium sulphide in every 100 pounds of slag, according to the following figures. By the analysis every 100 pounds of slag contains 3.84 pounds of sulphur CaO + S = CaS + O, or according to atomic and molecular weights,

$$56 + 32 = 72 + 16$$

Let x = the Ca S required for 3.84 pounds of sulphur, then

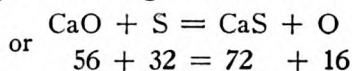
$$32 : 3.84 :: 72 : x$$

$$32 x = 276.48$$

$$x = 8.64 \text{ pounds of Ca S}$$

A 300-ton blast furnace makes on an average of 12 ladles of cinder per day on foundry iron, and foundry iron slags contain the highest percentage of combined sulphur. An average weight of each cinder

ladle is about 18 tons, hence 12 ladles are equivalent to 216 tons of cinder per day. Assuming the above analysis to be that of the slag then 8.64 per cent of the 216 tons of slag or 18.66 tons are calcium sulphide. Again referring to the reaction



we find that 56 pounds of CaO = 72 of CaS or

$$56 : 72 :: x : 18.66 \text{ ton}$$

$$72 x = 1044.96$$

$$x = 14.50 \text{ tons of CaO}$$

But CaO = 56 per cent of CaCO_3 . Hence the required $\text{CaCO}_3 =$

$$14.50 \times \frac{100}{56} = 25.89 \text{ tons of } \text{CaCO}_3.$$

The ordinary limestone is not pure CaCO_3 , hence we will assume this to be but 95 per cent of the stone. Then 25.89 ton of CaCO_3 will equal 27.55 ton of raw stone required to flux all the sulphur going into the furnace in 24 hours. In round numbers approximately 50,000 pounds of stone are required to take care of the sulphur under these conditions.

Now suppose the furnace conditions change and the slag comes out but 1.60 per cent of sulphur in the

slag. Then $50,000 \times \frac{1.60}{3.84}$ or 20,833 lbs. are needed and therefore 29,167 pounds too much stone are going into the furnace. This extreme excess stone fluxes the silica which on account of the furnace being cold has come from the silicon in the iron. Thus as conditions grow worse and the furnace gets colder the silicon in the iron goes down and the sulphur goes up. This accounts for the extremely low silicon, high sulphur irons when a furnace cools off from being too heavily limed. Often when this sulphur rises additional lime is added, making conditions even more extreme. This accounts for the very heavy infusible slag that at times fills the bottom of the furnace closing up the blowpipes and often ultimately ending in a shut down.

It is seen from the above example, that the remedy for such conditions is to take off lime, and not to put more on, for the excess lime uses up the silica, which in turn when taken from the iron, makes the furnace cold. For this very reason foundry irons or high silica irons require low bases and a high hearth temperature. The silicon in iron is heat or rather it has taken heat to put it there, hence a hot bottom. The reverse is therefore true, very low silicon iron with excessive lime means a low hearth temperature and cold bottom.

The largest amounts of calcium sulphide are found in foundry iron slags which are generally high in alumina. Here the alumina distinctly plays the part of a base and fluxes the silica, while the lime fluxes the sulphur and to a small degree the silica. These slags bear the distinct blue color of aluminum, but just as

soon as the bottom gets cold they become glassy, due to the silicon going into the slag as silica. If the furnace bottom gets cold enough the slag will be cream white, showing a lime silicate and the sulphur will show a corresponding rise in the iron.

A specific example of the change from combined sulphur to free sulphur, and a blue slag changing first to one of glass edges and then to a pure white lime silicate, is shown by the following analysis of iron and cinder.

Illustration I

Si. O ₂	Al ₂ O ₃	Bases	Free Sulphur	Iron Analyses
30.18	17.44	49.09		Si. Sul.
Blue Aluminum Silicate				
30.58	17.22	48.88		3.06 .021
Blue Aluminum Silicate				
33.02	15.20	48.51		2.46 .033
Blue Center Glass Edges				
34.48	15.02	47.08		1.93 .026
White Lime Silicate				
				— .048
				— .044
				— .065
				47 .082

In the first slag most of the sulphur is combined with the lime hence but .020 sulphur in the iron. As the furnace starts to grow colder the silicon drops from 3.43 to 3.06 with a corresponding rise of one point in sulphur. With still further drop in temperature the silicon drops to 2.46 and the sulphur rises to .033. Note that the loss of silicon in the iron shows a gain of 3 points of silica in the slag, when the sulphur in the iron reaches .048 the slag has become a

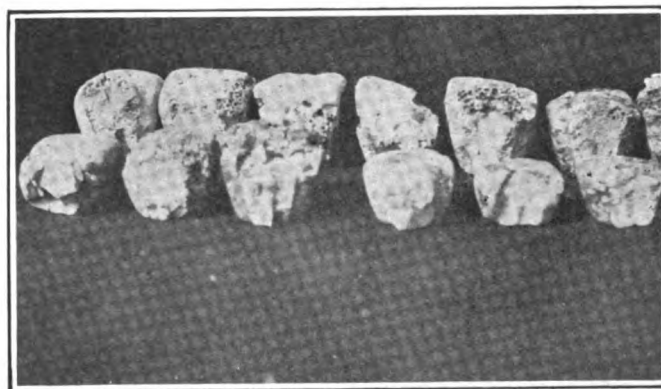


Fig. 1.—Slags high in combined sulphur—Hot bottom, low fusion zone, heavy lime.

white lime silicate slag, and the large increase of silica in the slag has taken the lime away from the sulphur. Finally the extreme is reached in an ink black slag with the iron analyzing .47 in silicon and .082 sulphur.

With a hot furnace, heavy lime and high sulphur ores on the burden, the gas becomes very heavy and smoky. An extremely heavy white fog also rises from the cinder as it is run from the furnace. The writer collected some of this heavy white deposit from the monkey and tuyere stock and had it analyzed. The an-

alysis showed 4.20 per cent CaO and 10.73 per cent sulphur. This is extremely interesting for it seems to show the slag very heavily oversaturated with calcium sulphide which on reaching the atmosphere under reduced conditions of temperature and pressure,

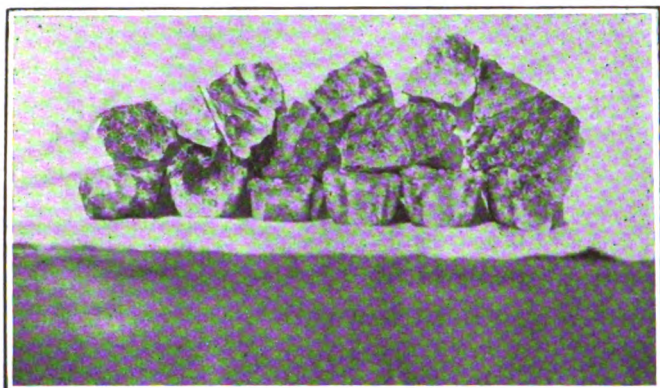


Fig. 2.—Dipper samples, note the pieces are solid and contain no gas cavities.

escapes as heavy white fog or fume rising from the slag.

Indirectly calcium sulphide effects the condition of the carbon in the pig iron. With very heavy lime, a hot bottom and high combined sulphur, the cast house is generally filled with graphitic carbon. In other words the lime sulphide seems to promote the formation of graphitic carbon, for iron with low sulphur made on a hot lean furnace will not show any graphite at all.

This is the cause of extremely, dry, mushy iron. Carbon gives the iron fluidity, and the removal of such large amounts in the form of graphite cause it to be dry and pasty.

It is interesting to note the effect which this also has on the driving of the furnace. A hot, heavily limed furnace will drive very slow and even stick and hang if too hot. The silicon is the main component of slags which makes a furnace drive. Just as soon as the lime increases to such an extent, as to dry up the slag, then the furnace stops driving. This is done automatically on a hot furnace for the heat drives the silicon in the iron thus automatically increasing the lime.

Very high combined sulphur is always the result of a low fusion zone. When the wind has been thrown off at cast time the tuyeres will be perfectly dry and nothing but white hot coke will be seen. When the furnace starts to get dry at cast time, heavy white lime fumes roll from the tapping hole. These fumes smell strongly of lime.

Figure 1 shows slags which carry high combined sulphur. They have been made on an extremely hot bottom with heavy lime. Figure 2 shows slags which are not quite as hot. Black streakings may be seen through the samples. Note that there are no gas cavities in these pieces. Figure 3 shows two sets of dip-

per samples. Those on the left are full of gas cavities due to free sulphur, those on the right are solid and smooth showing most of the sulphur to be in the combined form. Figure 4 shows very heavy lime with the furnace just starting to go cold. The sulphur is still very low and in the combined form as seen from the tops of the iron samples. In Figure 5 the furnace has gone cold and is making low silicon high sulphur iron. The large sulphur holes can plainly be seen in the last iron sample. The sulphur is now free sulphur and has gone into the iron while the lime has attacked the silica which is formed by the drop in silicon in the iron.

A glance at some slag analysis will show the relation of combined sulphur and free sulphur with reference to the grades of iron made.

Foundry Iron.					
Silicon	2.15	2.13	2.24	1.98	2.29
Sulphur	.039	.042	.038	.040	.033

Slag Analysis.					
SiO ₂	Al ₂ O ₃	CaO	MgO	Fe	Sul.
31.48	18.08	38.70	8.82	.49	2.43

Basic Iron.					
Silicon	.66	.60	.64	.96	.87
Sulphur	.033	.031	.033	.021	.023

Slag Analysis.					
SiO ₂	Al ₂ O ₃	CaO	MgO	Fe	Sul.
32.98	13.26	45.30	6.30	.56	1.34

A comparison of these two slag analysis shows over 1 per cent more combined sulphur in the foundry iron slag than in the basic iron slag with a difference of 8 per cent of lime.

This again brings up a discussion of the heating value of the gases from different furnace burdens. When a basic furnace goes off the gas at times becomes extremely poor. Under the boilers it is seen to burn with a thin blue or purple flame. The heating value is very low and coal is often needed to hold the

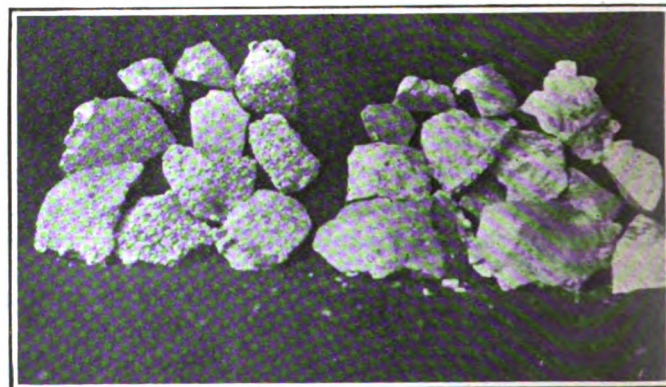


Fig. 3.—Dipper samples—Those on the left show gas cavities, due to free sulphur, those on the right are solid and smooth and most of the sulphur is in the combined form.

steam. The cause is that there is little or no carbon in the gas. The free sulphur puts all the carbon in the iron as combined carbon which makes the iron thin and fluxed like water. Such extreme fluidity is not needed, so just as soon as the furnace starts to

come round and the sulphur increase as combined sulphur, then the carbon again starts to go into the gas and it will be seen to burn with a yellow flame at the boilers. It is interesting to note how hot and yellow the gas becomes when a heavy extra coke blank comes



Fig. 4.—Very heavy lime—Furnace starting to go cold—Sulphur still in the combined form, as seen from the tops of the iron samples.

down. The large excess of carbon furnishes a liberal supply also to the gas and its heating value at once becomes noticeable.

The question might be asked, "Why do basic iron slags generally show less combined sulphur than foundry iron slags?" The answer is this; generally in making basic iron the silicon has a tendency to go over 1 per cent. In order to keep the silicon within the required limits, cold air is run into the bottom with the stove heat. This cold air separates the lime from the sulphur and it is carried out as free sulphur. Continued use of cold air raises the fusion zone up to, or above the mantle, in turn giving a cold bottom which promotes free sulphur.

Often the fusion zone is down in basic iron and the bottom very hot. Slags made under these conditions are high in combined sulphur.

It is very seldom that any slag shows all the sulphur combined even under favorable conditions. With slags showing even the highest combined sulphur, still there is some free sulphur. Wherever there is a gas cavity it is a sign of some free sulphur. The very high aluminum slags of foundry iron which are solid, dry, dense, and grainy are slags which carry the highest percentages of combined sulphur. From a few of the facts stated above one may distinguish foundry iron slags. For example, slags carrying 1.75 per cent or over of sulphur are those from foundry irons, those under 1.75 per cent sulphur would be classified as from basic irons. This is a general statement, but one which when coupled with other details will help distinguish a slag when absolutely nothing is known about the iron made.

From time to time discussions have appeared as to the maximum amount of sulphur that a slag can carry. The example given—3.84 per cent is the highest which has come under the writer's observation,

but it would seem that even this might be exceeded. For example, with a very high sulphur coke, and a very high sulphur ore on the burden under conditions of a low fusion zone and high hearth temperature even a larger quantity than this might be found.

The average basic slag falls under 1.75 per cent sulphur and the average foundry iron slag varies between 1.60 and 2.50 per cent of combined sulphur. The combined sulphur is mainly dependent on the total sulphur going into the furnace, the position of the fusion zone, the hearth temperature, and the slag volume.

It is interesting to note the relation which the sulphur in slags has to slag volume. Assuming the total sulphur going into a furnace practically constant and all furnace conditions the same, then by changing the slag volume the sulphur will show an increase or decrease in proportion as the slag volume is increased or decreased. If the total sulphur is practically the same and the slag volume be decreased, then the slag will show an increase of sulphur. This is easily seen, just as a spoonful of sugar would be to a glass of water, or to a bucket of water.

When the sulphur in a slag is largely combined the running cinder is clear, clean, and sharp looking, when a large part of the sulphur is free sulphur, the slag has a greasy, oily, scummy appearance.

The relation of free sulphur, combined sulphur, and lime to the fusion zone are shown by the following three slag analysis. No changes of any kind were made, the fusion zone simply came down from the mantle to the hearth.

Slag Analysis.

	High	Starts down	Down
	1	2	3
Silica	34.78	33.48	33.38
Alumina	13.31	12.64	11.24
Bases	49.11	51.14	53.08

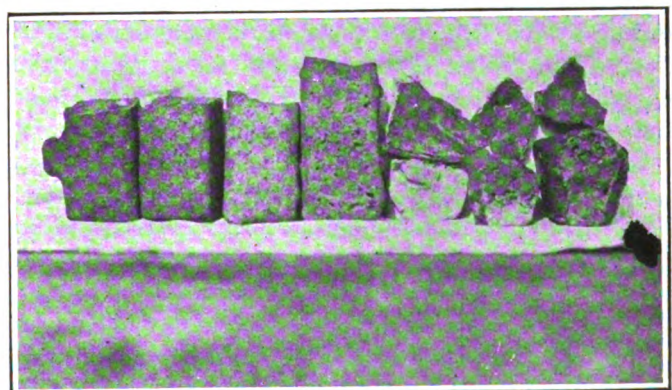


Fig. 5.—Furnace gone cold—Free sulphur, as shown by blow-holes in last iron sample.

In the first slag a very large part of the sulphur was carried off as full sulphur and suffocating thin blue sulphur fumes were given off at flush time. In the third slag heavy white fumes were given off and the odor of sulphur had practically disappeared. The

furnace was hotter and the iron lower in sulphur. This shows the automatic increase of lime due to the lowering of the fusion zone and decrease of slag volume. The loss of silica in the slag is accounted for by the increase in silicon in the iron. The decrease of sulphur in the iron shows an increase in the slag and the slag shows that there has been a very large increase in the combined sulphur.

It is interesting to compare what might be termed the saturation of two slags. The analysis of two different furnaces will bring these facts out clearly that the slag volume, conditions of temperature and pressure, and most important of all the total amount of sulphur going into the furnace, all influence the equilibrium of the individual slag components and determine the amount of sulphur which shall be removed as calcium sulphide in the slag.

	I Heavily saturated Calcium sulphide slag	II Less saturated slag Almost same analysis
SiO ₂	31.64	31.50
Al ₂ O ₃	14.00	16.00
Bases	49.36	49.10
Sulphur	3.84	2.35

Slag Number I is a typical slag from a furnace

with a very high sulphur coke and pyrites cinder ore going into the furnace. The total amount of sulphur going into furnace was from 5 to 6 per cent.

Slag Number II is a typical slag from a different furnace on lake ores and good coke, the total amount of sulphur going into the furnace falling well under 2 per cent.

A comparison of the two shows number I to be very, very, much hotter, made in a furnace where the whole furnace was hotter and more time was used; heavier denser white fume or fog rose from the slag when running, the slag was much thicker and heavier, and the slag volume was less.

As a general thing a slag carrying over 2.50 per cent sulphur is considered high in combined sulphur and it is high for furnaces on lake ores because practically the only source of sulphur to amount to anything is in the coke. Very high sulphur coke and ores require an extremely large amount of lime and therefore when the lime used to flux the sulphur is set free as an excess to flux the silica, these furnaces become much more violently limeset. The amount of calcium sulphide a slag will carry is first of all a function of the total amount of sulphur going into the furnace.

Roll Design for Shrapnel and Shell Bars

Box and Edging Passes for Heavy Drafts—Description of Angle Grooves, Finishing and Roughing Rolls—Qualities of Steel for Rolls—Elements Influencing Accurateness of Finished Product.

By W. S. STANDIFORD.

Immense quantities of shrapnel and high-explosive shells have been made in this country for the allies, and since the United States has entered into the conflict; considerable amounts of munitions will be required by the American forces. As steel bars are the basis from which the shells are manufactured, the designs of the rolls, their proper adjustment and handling should be subjects of much interest. The metal from which the projectiles are made, are round steel bars produced by rolling, the latter process making a dense and fine grained metal, well suited to the exacting processes of machining which it undergoes before the shells are ready for use in the guns.

It may be thought that the shells could be made faster and better from castings containing the chamber for the powder and bullets, thus leaving very little metal to remove in the lathes and other machines, instead of having to punch a hole in a solid steel blank and then finish the interior and exterior, as is done with each projectile made at the present time. The reason that castings are not used for this purpose is, that cast steel is a metal that usually contains air holes, thus making it a dangerous material for shells, as they would be liable to burst in the guns. Another rea-

son is, that the weight and balance of a shell made from a solid bar, has a steadier flight through the air than one made from a casting, as in the latter case, the heavier ingredients of the steel settle to the bottom during cooling, this combined with the presence of air holes in the metal make certain parts of the walls of the projectiles heavier than others which disturbs its balance during flight.

In steel bars, as a munition material, the carbon and other ingredients are equally distributed, inasmuch as the rolling process mixes them up making the metal fibrous in character. The size of the round bar rolled is 3½ inches in diameter. This is the size used to make the 18-pound projectile used in British field guns, sufficient metal being left on this sized bar to allow for the machining operations to make the finished product. The roughing rolls are three-high, the latter reducing the metal very quickly as compared with the two-high design. Quick reduction of the hot steel at the start, is most important, as it is necessary to reduce the steel as rapidly as possible while it has a high heat. This makes it fibrous, which is a quality desired, as this is the condition that makes for strength in iron

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and steel. Referring to the roughing rolls shown in Fig. 1—it will be seen that each roll contains a box and edging pass, while the others are put in on an angle. Box and edging passes, by their shape, allow very heavy drafts to be used.

The first and second passes work the metal on the top and bottom, there being very little work done on the sides. As will be observed by inspection of the photograph, the sides are put in on an angle, slanting toward the top of the groove. This is done so that the bloom will leave the pass easily. If the sides were straight, the bloom would stick in the pass, some of the metal being forced between the collars of the rolls, which would be liable to break under the tremendous pressure exerted by the engine. In actual practice, the sides of the box and edging passes are opened out 6 degrees toward the top; the width at the bottom of the pass being just wide enough so as to grip the bloom tightly. This prevents it from turning over on its side. The box, edging and angle passes all contain fillets at the bottom. This is done so that the corners of the bloom will be worked as much as possible, so as to make all parts of the bar uniform in strength. The roughing rolls are made of either cast iron or steel, the latter being the best, as it withstands rough usage better; it occasionally happens that a pair of tongs will slip out of the rougher's hands and go into the rolls. If they are made of cast iron, a collar will be broken off, thus the set will be idle until a new roll can be turned. Should a pair of tongs go into a set of steel rolls, it will be cut in two—the collar edge where it cut the tongs will be dented, which does not prevent the rolls from working.

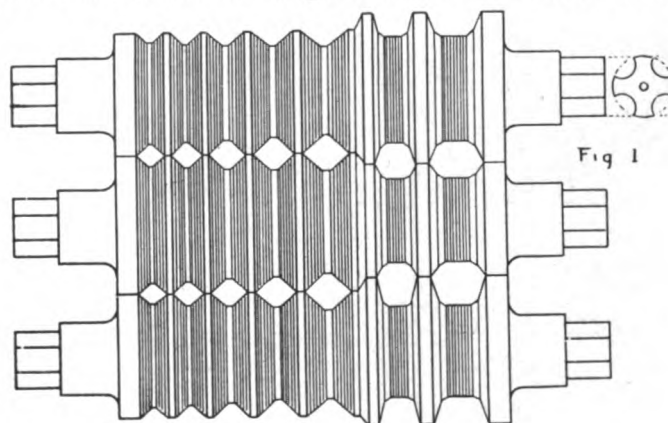
As it takes a blacksmith about two hours to make a pair of tongs; while it will consume about one week's time to turn a new roll; it will readily be seen that steel roughing rolls are more economical than cast iron ones. In purchasing steel rolls, it is best to get a metal having a high carbon content; as they will wear much better in the mill and do not bend; which latter characteristic is usually seen in the small-sized guide roughers used in a 10-inch mill. Steel rolls give good satisfaction to the users if the carbon content is high enough. Following is a chemical analysis of roll steel which is considered "next to the ideal metal," by chemists. The writer knows from actual experience that rolls of this analysis have withstood the roughest kind of usage in the mill, and have lasted long in the housings before requiring dressing in the lathe.

Carbon combined	.49
Silicon	.211
Sulphur	.036
Phosphorus	.041
Manganese	.8

To make the $3\frac{1}{2}$ inch round bars, Bessemer or open hearth steel blooms eight inches square and $2\frac{1}{2}$ feet long are used. Heated to a white heat in the furnace, they are pushed through the box and edging

passes, emerging in the shape of a long square bar.

The work done on the bloom by the above passes, has so compacted the metal, that when the angle grooves are reached there is very little flashing of molten steel coming from the bar, as is the case when the bloom first enters the rolls. In the photographs of the drawings of the roughing and finishing rolls that accompany this article, the full number of grooves in both sets are not shown,—this is done for clearness in the pictures, and also to keep their size down within reasonable limits. It being the usual custom in most mills, to have duplicate passes put in the finishers, containing the sizes of bars that there is the most demand for. This enables them to remain a long time in the housings before requiring dressing. The idea being to have most all of the grooves equally worn before sending the rolls to the lathe. This keeps down the expenses, as it would not pay to send a set of rolls to be dressed with only one or two of the passes worn rough and out of shape, while the others are in good shape. Each time a set



Roughing rolls.

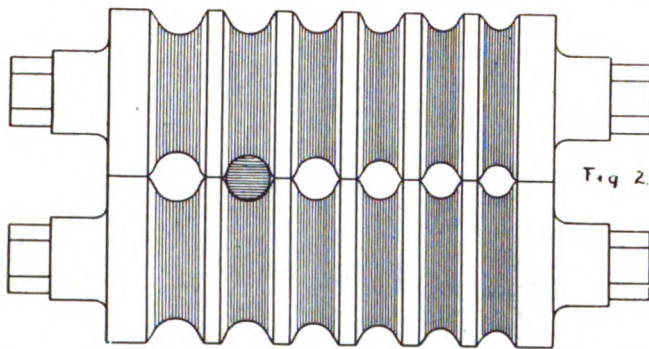
of rolls are dressed, they are made smaller in diameters until a time arrives when they are too small for the mill and have to be thrown away—hence the value of duplicate grooves in rolls for making the most called-for sizes of steel or iron bars.

The angle grooves come next in description. These have an angle of 95 degrees, and by their position in the rolls, work the bar mostly on the top and bottom corners, the corners of the bar at the sides have no work done upon them while the bar is going through one pass. Before it goes through the next smaller groove, the bar is turned over at a right angle to its previous position, thus the two corners which were at the sides of the pass, have work done on them.

The bar goes through the angle passes alternately, until it is reduced to four inches in diameter, then it is ready for rolling in the hand rounds or finishers illustrated in Figure 2—which is described next. These are usually two-high as the metal from the roughing rolls has been so reduced in size that the finishers quickly bring the bars to the correct size and shape in a few passes as will be seen by the de-

scription of the rolling of a bar. Hand round rolls are generally made out of a hard cast iron, although some mills use chilled rolls for making their hand rounds. The chilled cast iron ones last longer in the mill before requiring dressing, but being very brittle, the collars between the passes are liable to break out if a sliver on a bar should wedge itself between them.

The grooves in the hand rounds are put in by means of round steel plugs, made as hard as fire and water can make them. They are ground after hardening, as the latter throws them out of true circular form. Tools for use on the roll lathe, work best when left as hard as it is possible to get them. The pass is cut down in each roll to nearly half the diameter of the plug, sufficient clearance being allowed, so that when in the mill the rolls will not have to touch each other; $\frac{1}{8}$ of an inch clearance being the usual allowance. This is to prevent the collars between the passes from breaking out on their peripheries, which is liable to happen when rolls are



Hand round finishers showing proper clearance of passes for bars.

pressed against each other while they are working. After the groove is turned in the roll to the proper depth, the steel plug is withdrawn and a tool put in that widens the sides of the pass near the top and rounds the corners at the same time, but does not touch the center. This tool is then removed, and the pass with its cut away sides has the appearance illustrated in Figure 2. The other grooves in both rolls are turned the same way, care being taken to have them exactly opposite one another. The reason that the sides of each groove have to be cut away for a short distance near the top and joint of the rolls, is, to prevent a long ridge or fin on each side of the bar at the joints of the rolls.

The four-inch square bar from the roughing rolls goes once through the $3\frac{3}{4}$ -inch pass. It is then turned over at a right angle to its previous position, and pushed into the $3\frac{1}{2}$ -inch finishing pass. As the bar from the $3\frac{3}{4}$ -inch groove passes through the $3\frac{1}{2}$ -inch one, the metal spreads out in the extended sides and is about $\frac{7}{16}$ of an inch wider at the sides as a result. The part that touched the top and bottom of the pass being the correct size. It is then again turned over at a right angle so that the wide part will touch

the top and bottom of the grooves, and rolled again. The part of the bar rolled to the finished size now faces the cut-away portions of the pass, but does not touch it, therefore it keeps the right diameter while the wide part of the bar is being rolled. This is followed by again turning it to a right angle to its previous position and giving it its final rolling. The shaded outline of the finished bar indicates that the total width of the cut-away clearance part of the pass is slight. The last rolling which the bar receives, rounds out any slight inequalities on the surface that may exist. In the manufacture of round iron or steel bars by the use of rolls, it is impossible by rolling to produce a bar that measures the same on all sides; the variation from a true circular shape being about six one-thousandths of an inch, although some manufacturers by placing an extra set of rolls in front of, and at an angle to the regular ones, can make a bar having a variation of only three one-thousandths of an inch over size; which is about the best that can be done at the present time.

It is a fact that the consumers demands for exact sized rounds is increasing every year. To get such results in keeping the variation in size down to a few thousandths of an inch, requires the utmost care and skillful setting and handling of the rolls by the roller, and it also takes a roller who knows his business, as no ordinary amateur roller can set and maintain them in position to make accurate rounds. The best that the ordinary roller can do, is to make round iron or steel bars $\frac{1}{64}$ of an inch out of true circular form. This is due to their incorrect setting and handling of the rolls, such as inserting the metal at too high a heat in the finishers; not having the grooves in line, and not turning the metal over at an exact right angle at each rolling in the finishing pass.

Too low a temperature in the finishing pass, also influences the shape of the bar and makes it uneven in size. Thus when the bar has places on it that are relatively cold to other parts, in going through the rolls, the cold spots causes them to spring more than on the hot parts, thus making the bar larger in diameter at those places. If there are a number of cold spots on a bloom due to careless heating in the furnace, the finished bar will be wavy in appearance, it being absolutely necessary to have the metal at a uniform temperature and evenly heated all through if fine bars are desired. So it will readily be seen that the heater and roller must work together in order to satisfy the exacting demands of the consumer for as perfect rounds as can be made. In buying steel for shrapnel shells, the requirements of the purchaser are even more exacting; this makes the manufacture of shrapnel and high explosive shell bars a very expensive operation. As an example; bars for high explosive shells call for a discard of 40 per cent of the ingot; bars for shrapnel 30 per cent; and ordinary steel bars about 15 per cent.

Installation of Large Turbo-Generators

Specifications for Four Furnace Blast Furnace Plant—Comparisons of Gas Engine and Steam Turbine Plant; Segregated Gas Electric and Steam Turbine Electric Stations.

By RICHARD H. RICE, General Electric Company.*

Estimates have been prepared, using information of the utmost reliability, from plants in actual operation, of the elements of first cost and operating cost of complete blast furnace and steel mill plants driven by gas engines and by steam turbines as alternates. The size of plant chosen is one of four blast furnaces, each capable of producing 550 tons of pig per 24 hours, with a coke consumption of 1,800 pounds of coke per ton of iron. The necessary electric generating apparatus for a steel mill has been provided, of suitable capacity to utilize the blast furnace gas, and all the items necessary to constitute a complete, practical and modern plant have been included.

The units have been chosen with due reference to economy, flexibility and reliability, and in the gas engine installations include the largest units known to be available, with the usual spares. In the turbo-blower house one unit per furnace, as contemplated, has become standard practice, with two spares. In the turbo-generator station, the three 12,000 K.W. units chosen provide one spare and follow central station practice and experience in the use of the largest units which will give the flexibility desired.

TABLE NO. 1.
Comparative Costs for Four-Furnace Plants.

First Costs.	Gas Engine	Steam Turbine
Primary washers	\$ 131,250	\$ 131,250
Secondary washing station	300,000	.....
Gas pipe from boiler house	212,500	.....
Boilers and piping	167,500	628,800
Boiler house	41,250	123,750
Electric station apparatus	3,250,000	745,600
Electric station house	250,000	69,200
Blowers, etc.	1,812,500	726,416
Blowing station house	237,500	69,200
Pumping station, standpipe, conduits ..	787,500	293,484
	\$7,190,000	\$2,787,700

Charges—Dollars Per Year.

Running Charges	Gas Engine	Steam Turbine
Primary gas washers	\$ 2,100	\$ 2,100
Secondary gas washers	42,000	.....
Boilers	12,000	52,750
Electric station	90,000	68,250
Blowing station	49,500	42,000
Pumping station	6,000	4,000
Running charges, total	\$ 201,600	\$ 169,100
Fixed charges at 13 per cent	934,500	359,800
Coal for occasional deficiency of gas supply or excessive mill load, at 2.00 per ton	21,652	35,000
Total charges	\$1,157,752	\$ 563,900

* Abstract of paper read before the American Iron and Steel Institute meeting, at New York, May 26, 1917.

In considering the effect of first costs on charges, I have included fixed charges, which consist of taxes, interest and obsolescence or amortization. (Depreciation is included under running charges as repairs and maintenance, and under fixed charges as obsolescence.) Fixed charges are taken for both gas and steam plants as 13 per cent. This is a customary figure for gas-engine plants, while steam turbo-electric stations often use a lower figure in the neighborhood of 11 per cent. Therefore, the use of 13 per cent for both is relatively favorable to the gas engine. Fixed charges may be itemized as follows:

	Per Cent
Interest (on bonds or capital invested)	5
Taxes	1
Insurance	1
Obsolescence (amount laid by a sinking fund to replace or amortize the plant)	6
Total	13

Running charges include actual cost of operating the plant, and also maintenance and repairs, sufficient to keep the plant in first-class condition up to the time it is fully amortized. The only charges are therefore the fixed charges, the running charges and the cost of coal, for emergencies.

In order that it may be seen that all the saving in total charges is not realized in the electric station, Table 2 is given to show the first cost and charges of the electric station by itself.

TABLE NO. 2.
Segregated Electric Stations.

First Cost.	Gas Engine	Steam Turbine
Primary washers	\$ 46,400	\$ 46,400
Secondary washing station	244,000	.....
Gas pipe from boiler house	172,000	.....
Boilers and piping	128,440	483,900
Boiler house	33,500	85,000
Electric station apparatus	3,250,000	745,600
Electric station house	250,000	69,200
Pumping station, standpipe, conduits ..	180,000	127,750
	\$4,304,340	\$1,557,850

Charges—Dollars Per Year.

Running Charges.	Gas Engine	Steam Turbine
Primary gas washers	\$ 740	\$ 740
Secondary gas washers	34,150	.....
Boilers	9,750	36,200
Electric station	90,000	68,250
Pumping station	1,400	1,830
Running charges, total	\$ 136,040	\$ 107,020
Fixed charges at 13 per cent	560,000	202,000
Total charges	\$ 696,040	\$ 309,020

From a comparison of Tables 1 and 2 it will be seen:

Table 1.—Saving in first cost by use of steam turbines in complete plant, about \$4,500,000.

Saving in total charges by use of turbines in complete plant, about \$550,000.

Saving in first cost by use of turbines in electric station, about \$2,750,000.

Saving in total charges by use of turbines in electric stations, about \$380,000.

Attention should be called to the fact that the apparatus which has the lowest first cost has also the the lowest total charges. In other words, by refraining from spending \$4,500,000, a saving in total charges of over half a million dollars will be realized. It is usually the case that the apparatus of higher first cost has lower running charges which provide income necessary to take care of the fixed charges. In this case, the lower operating costs are partly produced by the lower fixed charges from the smaller investment and partly by the fact that the running charges of the lower cost apparatus are themselves lower.

The saving in total charges of the turbine plant over the gas-engine plant reduced to cost of the pig produced

attention of the management is largely fixed upon the question of production of pig iron and steel. The question of production of electricity and of blast are secondary.

The utilization of waste heat from open hearth and heating furnaces (and perhaps even from Bessemer converters), to the limit, and of by-product gas resulting from the manufacture of coke, the installation of modern steam turbine plants at all furnaces, capable of utilizing blast furnace gas to the maximum extent possible, and the tying together of all plants in a closely developed section like Pittsburgh by a suitable network of electric cables, will probably render it unnecessary to develop any power in such a district by the use of raw fuel. In fact, it is confidently believed that such complete utilization of the heat available in any of our large steel producing centers will render it possible to supply considerable electric energy for external purposes at a very attractive rate.

Specifications for Blast Furnace Plants.

Figures in the paper apply to an installation of blast furnaces in a steel mill of which the principal constituent elements are given below.

Blast Furnaces.—Four blast furnaces have been included in which it is expected that carbon will be consumed with a total amount of 12,835 short tons per furnace, per average month of 730 hours. This figure corresponds to an output of 550 long tons of pig per day with a coke rate of 1,800 pounds per long ton and considering 86 per cent of the weight of coke as net carbon passing into the gas.

By means of the following formula quantity of air and quantity of gas produced for each pound of carbon leaving the furnace in the gas given below. These computations are derived from a gas analysis and the values obtained are in cubic feet at 14.7 pounds per square in. and a temperature of 60 deg. F. and this quantity is substantially equal to cubic feet at 30 in. mercury and 62 deg. F. temperature.

N_2 = percentage of N in the gas.
C = the sum of the percentages of gases containing carbon.

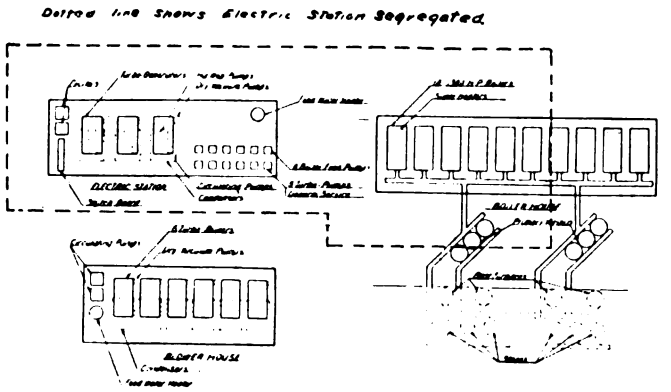
Then, $39.6 N_2/C$ = cubic feet of air per pound of carbon.
 $3140/C$ = cubic feet of gas per pound of carbon.

The air above computed is actual air after allowances have been made for slip, etc., and is the figure indicated on the governing beam of a turbo-blower with a properly calibrated air governing apparatus.

The carbon above referred to is the carbon in the gas and consists of the net carbon in the coke and in the limestone, etc., less the carbon in the pig, flue dust, etc.

The lower or net heating value of this gas is computed to be 95.5 B.t.u. per cu. ft.

Substituting in the above formulae the value of N_2 and C for the following gas analysis, we have for these furnaces:



Layout of Four Furnace Steam Turbine Plant.

in the plant per ton is, for complete plant, \$2.95; for electric station only \$1.93; for turbo-blowing station and pumping plant, \$1.02.

The thermal efficiencies of the segregated electric station comparing the two types of prime mover, including auxiliaries and emergency spares, are as follows on the basis of steady load condition:

Thermal Efficiencies of a Complete Station.	
	Per Cent
Best gas engine, as used in this paper	17.40
Good gas engine	16.25
Turbo-generator plant of paper	17.75
Largest turbo-generator plant	20.80

With variable loads the thermal efficiency of the turbine plant will hold up closely to these figures, while the gas engine plant is known to fall off considerably under such operating conditions.

It should be pointed out that one of the difficulties connected with maximum utilization of the heat units available in the gas from blast furnaces, arises from the fact that utilization of these heat units is only one of the incidents necessarily attendant upon the operation of blast furnaces and the operation of steel mills. The

Cu. ft. of air per lb. of carbon = 57.9

Cu. ft. of gas per lb. of carbon = 80.1

The total heat in the gas will then be:

$12,835 \times 2,000 \times 80.1 \times 95.5 \times 4/730 = 1,076$ million B.T.U. per hour.

The gas analysis used for this case is as follows:

	Per Cent
CO	26.2
CO ₂	12.9
CH ₄	0.1
C = Sum of gases containing carbon	39.2
H ₂ =	3.5
N ₂ = Nitrogen by difference	57.3
	<u>100.0</u>

All the gas produced passes through primary washers, and 30 per cent of the gas is assumed to be used in the stoves.

General Characteristics of the Plant.—The plant is laid out to be capable of supplying all blast furnace demands for air, water, steam and electricity, and also during week-day hours to supply to steel mills, per furnace, 4,450 gallons of water per minute and 5,000 K.W. of electricity, or a total for the plant of 17,800 gallons of water per minute and 20,000 K.W. of electricity. When the gas is insufficient to generate sufficient power for the full output of the steel mills, coal must be used to make up the deficiency. The cost of this coal is included in the figures of Table 1, last item under charges, at \$2 per long ton delivered at fire-room door, and containing 13,500 B.t.u. per pound.

The gas-engine plant has apparatus provided for burning this coal in such emergencies.

The entire plant in either case is assumed to be located on a river or a great lake, and it includes apparatus for unloading ore, storing it and delivering it to the furnaces; and water is supposed to be of such quality that it is proper for use without purification. There is also included in the figures a water intake system with conduits and standpipes.

Four-Furnace Gas-Engine Plant.

This plant includes a gas electric and a gas blowing station; also an electric pumping station. There are steam spares provided in all cases for emergency use. This includes a boiler house supplying regularly a small amount of steam for various purposes connected with the plant, but with sufficient reserve capacity so that by coal firing, steam for the emergency spares may be supplied when necessary. Gas holders are provided to store a comparatively small amount of gas, and furnace gas can be turned on or off and used under steam boilers as occasion demands, coal being used to make up any deficiency. The average amount of coal used for make-up is small.

The system includes a considerable reserve of boilers and steam spares which have been found necessary in practice, so that the blast furnace, steel mills and pumps will never have to be shut down.

Boiler Plant for Gas Engine Station.—The follow-

ing table shows the steam used in million pounds per month in this boiler plant:

Tests of steam pump spares	1.02
Tests of steam blower spares	4.58
Operation of electric station steam turbines....	23.57
Power station, miscellaneous	2.13
Gas washer station, miscellaneous	0.47
Blast furnace, miscellaneous	9.47
total steam	<u>41.24</u>

The following quantities are used:

Heat added in boilers—1,135 B.t.u. per pound of steam.

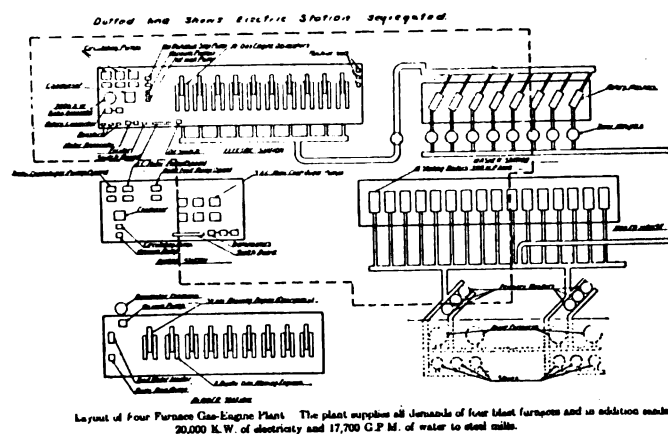
Heat consumption of boilers at 70 per cent efficiency— $1,135 \times 41,240,000/730 \times 0.7 = 91.6$ millions B.t.u. per year.

Coal used in addition to gas—8,661 long tons per year.

Heat from coal—29.9 million B.t.u. per hour.

Heat from gas by difference—61.7 million B.t.u. per hour.

Cost of coal consumed, at \$2 per ton with 50 cents



Layout of Four Furnace Gas-Engine Plant.

additional for firing—amounts to \$21,652 per year.

Gas Electric Station.—Alternating current circuits are provided which are supplied by gas-driven electric generators; one of these circuits has steam turbines floating on the line at light load which are capable of taking greater load in emergencies. Direct-current circuits are also supplied by gas-engine-driven generators with rotary convertors tied in and operated with alternating-current circuits for emergency use. Gas engines are installed with a maximum capacity of 30,000 K.W. and a steam turbine with a capacity of 2,000 K.W.

Power Distribution in K.W.

	K.W.
Blast furnace, miscellaneous	727
Pumping station	1,800
Secondary gas washers	850
Blowing Station	57
Electric station, miscellaneous	650
Steel mills	20,000
Total power	<u>24,084</u>
Steam-turbine power	725
Gas-engine power	23,359
Total power	<u>24,084</u>

The best gas-engine plant investigated shows 21 per cent efficiency, corresponding to 16,250 B.t.u. per K. W. hour. This figure corresponds to a total heat in gas supplied to the gas engine for electric station of $23,359 \times 16,250 = 380$ million B.t.u. per hour. Another plant, before referred to, gave 17,630 B.t.u. per K.W. hour. This figure is not here used.

The maximum amount of electric power which is needed for week-day hours in the steel mill is 20,000 K.W., that is, 5,000 K.W. per furnace. The gas from the furnaces is, on the average, more than sufficient to furnish this amount of power, but on account of fluctuations of both load and gas, a greater load than that above specified would involve shut-downs of the mill for unduly protracted periods when the gas is bad, or else it would involve undue expenditure for make-up coal.

Gas Blowing Station.—Seventy-four cu. ft. of blower displacement have been provided per pound of carbon. The blowing engine gas consumption is taken at 8,534 B.t.u. per gas I.H.P. hour. This is a test figure for the best plant investigated with an engine having limited overload capacity. The other plant gave 15,000 B.t.u. per gas I.H.P. hour. The average ratio of theoretical adiabatic air card to gas indicator card is 0.844. The air-tub displacement per furnace is $12,835 \times 2,000 \times 74/730 \times 60 = 43,400$ cu. ft. per min. The average theoretical power of adiabatic compression (at 15 pounds per sq. in. air pressure) is 5 HP. per 100 cu. ft. of air per min. Gas blowing engine I.H.P. per furnace is $434 \times 5/0.844 = 2,571$. Gas blowing engine heat consumption is $8,534 \times 2,571 \times 4 = 88$ million B.t.u. per hour.

PUMPING STATION.

Water Distribution in Gallons Per Minute.

Primary washers	123
Secondary washers	2,850
Boiler feed pumps	117
Electric station	6,840
Blowing station	1,760
Blast furnaces	10,910
Total plant water	22,600
Total steel mill water	17,800
Total water	40,400

Heat balance for complete gas-engine plant:

	Million B.t.u. per hour	Per Cent
Boilers	62	5.8
Electric station	380	35.3
Blowing station	88	8.2
Stoves	323	30.0
Margin	223	20.7
	1,076	100.0

The cost of the complete plant, including reserve boilers and steam spares in electric and pumping station, are given in the first column in Table 1 in the main body of the paper, and need not be here repeated.

Four-Furnace Steam Turbine Plant.

This plant is equipped with large, modern boilers, with all improvements and with economizers. The boilers can burn coal as well as gas. The steam conditions are such as would be used in modern stations,

235 pounds per sq. in. gauge, 200 deg. superheat, 28.5-in. vacuum. There are motor-driven, circulating pumps directly connected to the generator and blower steam turbines and not included in the general pump station. Throughout the plant motor-driven auxiliaries are also used with enough steam driven auxiliaries for emergencies, and to heat the feed water to an amount consistent with the best efficiency of the boiler economizers.

Turbo-Electric Station.—There are three turbo-generators rated at 12,000 K.W. continuous load; two of these to be operating continuously and one to be a spare, for regular week-day load. There are small motor-generator and turbo-generator sets for excitation, feed-water heating, etc.

Power Distribution in K.W.

Blast furnace, miscellaneous	727
Auxiliary power, exciter, etc	1,673
Steel mills	20,000
Total power	22,400

Water rate for average load, 12 pounds of steam per K.W. hour. Average steam consumption of turbo-generator, $12 \times 22,400 = 268,800$ pounds per hour.

Turbo-Blowing Station.—Six turbo-blowers are provided, one for each furnace and two spares. Allowing 3 per cent for time out and stove losses, and using 57.9 cu. ft. of air per pound of carbon, as previously deduced, we have as the capacity of the blowers $12,835 \times 2,000 \times 103 \times 57.9/730 \times 60 = 35,000$ cu. ft. per min. Steam consumption of a high efficiency centrifugal compressor at an average air pressure 15 lbs., 1.08 lbs. of steam per 100 cu. ft. of air. Total steam consumption of blowers $350 \times 1.08 \times 60 \times 4 = 90,800$ pounds per hour.

Pumping Station for Steam Turbine Plant.

Water Distribution—Gallons Per Minute.

Make-up and general losses	410
Blast-furnace water	10,910
Turbo-blower water	1,200
Total plant water	12,520
Total steel mill water	17,800
Turbo-generator circulating water	37,600
Turbo-blower circulating water	12,700
Total water	80,620

The circulating pumps are directly connected with the generators and blowers, and their costs are included therewith.

Boilers rated at 2,500 HP. each are used with economizers and feed-water heaters using exhaust steam from auxiliary apparatus.

Steam Consumption Table—Lbs. Per Hour.

Total non-condensing steam for heating feed water	9,100
Turbo-generators	268,800
Turbo-blowers	90,800
Total steam	368,700

The temperature of feed water at entrance to boilers is taken as 210 deg. F., and 6 per cent of the total heat of the gases is counted as available in the economizer. To

reach this temperature of 210 deg., the balance of the heat necessary to bring water from hot-well temperature to 210 deg. is supplied by noncondensing steam and feed-water heaters. This arrangement calls for a comparatively small amount of non-condensing steam. Other feed-water heater arrangements are possible with practically the same over-all efficiency. The main boiler raises the water from 210 deg., utilizing 75 per cent of the heat in the gases, corresponding to 75 per cent boiler efficiency. Total heat of the steam above 210 deg. is 1,136 B.t.u. per pound. Total heat in the gas, 368,700 $\times 1,136 / 75 = 558$ million B.t.u. per hour.

The steam-turbine plant, therefore, by these figures, requires slightly more heat than the gas-engine plant.

The heat storage capacity in the boilers is considerably more than exists in the gas-engine plant, so that probably no more make-up coal will be needed than in the gas-engine plant. However, in order to make this comparison conservative, no consideration is given to this and enough coal is provided for, in addition to that provided for in the gas engine plant, to make the apparent surplus or margin the same. This calls for an additional 28 million B.t.u. per hour, requiring coal costing \$13,350 per year additional to that in the gas engine plant.

Heat Balance for Complete Steam-Turbine Plant.

	Millions B.t.u. per hour	Prev. value of gas plant
Pumps, generators and blowers	558	530
Stoves	323	323
Margin	223	223
Total	1,104	
Deduct heat from coal	28	
Heat from gas	1,076	1,076

The costs of the complete plant are given in the second column in Table 1 of the main body of the paper and need not be here repeated.

Segregated Gas-Electric Station.

In order to enable a better comparison to be made of the electric stations in the steam and gas plants, all of the items in each case pertaining directly to the electric station are brought together. This, therefore, provides an electric station using gas-engine-driven generators fed by blast furnace gas and including the necessary gas washing station and pumping station to supply the exact amount of gas and water for the gas electric station only. In the complete plant, as already mentioned, there were boilers for supplying the amount of steam regularly needed about the plant and for reserves for emergencies. That fraction of these boilers which is proportionate to the amount of gas used in the electric station is herein included in the cost of the gas electric station. This is necessary to give a station which will supply the requisite amount of electric power in any emergency.

Power Distribution in K.W.—The total power provided for the electric station is, of course, the same as in

the complete plant previously given. However, in order to consider the electric station by itself we must segregate the amount of this power required about the electric station itself and for the gas washing and pumping station appertaining to the electric station.

	K.W.
Pumping station	410
Gas washing station	690
Electric station, miscellaneous	600
Electric station total	1,700
External to electric station	22,384
Total power	24,084
Steam-turbine power	725
Gas-engine power	23,359
Total Power	24,084

Using the values previously alluded to in the section on Gas Electric Station of 16,250 and 17,630 B.t.u. per K.W. hour, respectively, we have as the heat consumption of the electric station 380 and 412 million B.t.u. per hour. The fraction of the boiler-house consumption of the complete plant appertaining to the electric station will be 59 million B.t.u. per hour. Hence the total over-all heat consumption of the electric station for the production of 22,384 K.W. comes out 471 and 439 million B.t.u. per hour for the two gas-engine efficiencies given; giving as values of B.t.u. per K.W. hour 21,000 and 19,600 corresponding to efficiencies of 16.25 and 17.4 per cent. These are net efficiencies of gas-engine plants on the basis of the best figures reported and of the figure obtained in the large plant, and including the power in all auxiliaries and emergencies, spares and reserves. These figures are comparative with gross heat consumption in the steam-turbine electric station next given.

Segregated Steam-Turbine Electric Station.

In the same way as the gas-engine electric station was segregated, we here segregate the steam-turbine electric station by including that fraction of the boil-

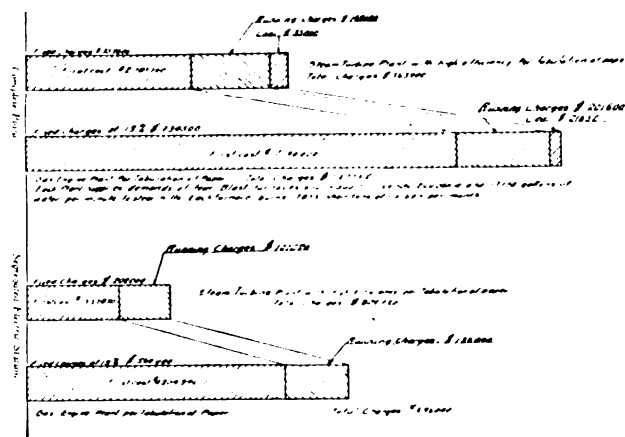


Chart of comparative charges for four furnace plants—The total lengths for each case give total costs of every kind, including fixed charges, repairs, maintenance and operation, and make-up coal—All figures are dollars per year.

ers and auxiliaries which belongs directly to the electric station:

Power Distribution in K.W.	
Electric station auxiliaries	610
External to electric station	21,790
Total power	22,400
Steam Consumption Table.	
	Lbs. per Hour
Non-condensing auxiliaries	6,750
Turbo-generator	268,800
Total steam	275,550
Total heat in gas — $275,550 \times 1,136/.75 = 417$ million B.t.u. per hour. This is for an output to the	

mill of 21,790 K.W., hence the heat consumption is 19,200 B.t.u. per K.W. hour. As will be seen, the efficiency of the turbo-generators is such as to make this somewhat less than the figure for the gas engine, including auxiliaries and reserves.

Comparison of Heat Consumption of Segregated Electric Stations.		
	Gas Engine	Steam Turbine
K.K. output external to electric station	22,384	21,790
Heat consumption, million B.t.u. per hour	439	417
B.t.u. per K.W. hour	19,600	19,200

The Elements of Roll Pass Design

Features Influencing Lateral Spreading of Steel in Rolls With Varying Conditions of Speed, Temperature, Reduction and Shape of Pass—Formula Considerations Showing Limited Range of Applicability.

By W. TRINKS.

The proper shaping of material in grooved rolls demands that the stock fill the passes, and yet not exert an excessive pressure against the side walls, for if the latter should occur there would be excessive power consumption, rapid wear, and the production of fins. For this reason knowledge of the influences which affect lateral spreading is of very great importance in roll design.

In the present discussion, the principal features influencing distribution and amount of spreading will be investigated. It will be found that there are many, so many, that no general formula for the spreading can be derived. And if it could be derived, it would be so complicated as to be useless for practical purposes.

It is evident that the shape of the pass affects the spreading; in fact, the influence of the shape is so great that it overshadows many of the elementary laws. For that reason the discussion will start with the simplest case, namely that of a flat rectangular pass.

Direction of Spreading.

In this simple case as well as in all others the following general rule holds: Each particle moves in the direction of least resistance. The difficulty is to foretell what that direction is, for any given particle. The smartest mathematicians have been unable to do so, and good judgment must be used. Let Fig. 1 be the center section of a flat pass. Let the entering section be a square. The distribution of forces in such a pass was investigated by the author in the April number of *The Blast Furnace and Steel Plant*, 1915. In order to illustrate the above-mentioned rule, first consider a particle at (1). It has "its back to the wall" and certainly cannot move to the left, because

the whole bar is being drawn into the rolls. It cannot move up or down, and there is some difficulty in moving to the right, because speed of reduction is less at (2) than at (1), and to move to the right it would have to increase the speed of the material to the right of (1). Consequently it exerts side pressure which acts parallel to the axis of the roll, or, in our illustration, at right angles to the plane of the paper. If the

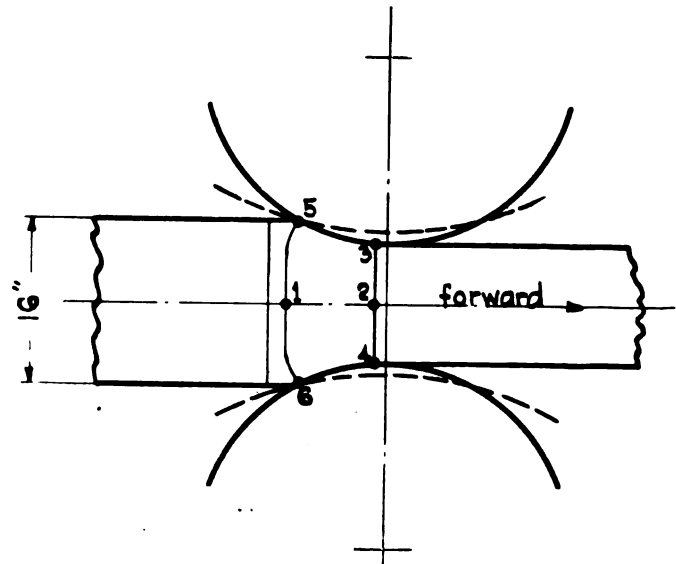


Fig. 1.—Location of points considered for action of forces.

reduction is small, as indicated by the dotted lines, then there is less resistance to movement to the right, and the tendency for producing side pressure is less. At point (2) there is practically no resistance to forward flow, while there is resistance to side flow; consequently there is very little spreading tendency. At points (3) and (4), on the other hand, friction between stock and rolls somewhat hinders forward flow

because the bar moves faster than the rolls; so that there is some tendency to spread. The opposite effect occurs at points (5) and (6). The material is drawn in by friction and is lengthened by tension in the direction of rolling. Tension causes lateral contraction, so that there would be negative spreading at these points, if it were not for the compression which also exists at these points at right angles to the direction of rolling.

If we now imagine Fig. 1 to represent sections nearer the outer edges, then we find the following difference. Resistance to lateral spreading is less at point (1) as well as at point (2). At point (1) the lateral motion actually occurs, while at point (2) the forward motion of the center section pulls the sides along in a manner which is more fully described below. In this manner the behavior of steel in flat passes is explained, because observation teaches that, with heavy reductions, the bar spreads first in the center, and then top and bottom.

Before the actual quantitative amount of lateral spreading is studied, another feature must be considered, namely, the influence of the projected contact area between stock and rolls. It is known that sheet bars do not spread in the last passes; it is likewise known that plates do not spread, but will, on the contrary, draw in under certain conditions. Here again, the rule of flow in the direction of least resistance, properly applied, furnishes the explanation.

Amount of Spreading.

A study of Fig. 2 will help. It represents a plan view of the rolls of a plate mill with the plate between them. The cross-sectioned area is the area of

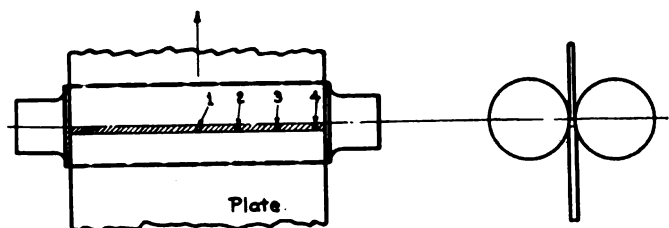


Fig. 2.—Plate in rolls.

contact or of compression. A particle at (1) cannot do anything else but go forward. Pressure is present to move it sideways, but, if it did follow that pressure, it would have to overcome the friction between rolls and stock all the way from (1) to (2). On account of the great distance between (1) and (2), this friction is very great compared to that in the forward direction, so that the particle (1) moves forward, and forward only. Similar reasoning applies to particles (3) and (4). When we come to particle (2), conditions are very different. Side friction is no larger than forward friction, so that lateral spreading might, at first thought, be expected. But, if side spreading occurred, forward motion would be lessened (due to volume remaining practically constant), and the plate

would elongate less at (2) than it does at points (1), (3) and (4). Such difference in elongation is possible to a very limited extent only, so limited that it is scarcely noticeable. The shearing strength of the plate pulls the edges along. Spreading due to compression, and lateral contraction by elongation completely neutralize each other so that the width of the plate remains unaltered. If this reasoning is correct it must be possible to actually reduce the width of the plate by not compressing the edges. This experiment is, in practice, never made with plates, but the same action occurs in the rolling of shapes. If, as indicated in Fig. 3, the web only is compressed, then the sides



Fig. 3.—Negative lateral spreading.

are "pulled down" and do not fill. If the flanges were bent over to form a flat plate as shown by the dotted lines in Fig. 3, the same action would occur. The projected area (Fig. 2) of a wide plate is one extreme, short and wide. The other extreme is found in blooming mills, see Fig. 4. Here the ratio of the sides of the

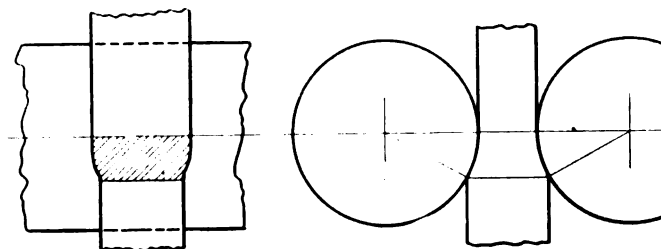


Fig. 4.—Shape of projected contact area in blooming mill.

roughly rectangular projected area of contact is approximately 1:2. It stands to reason that in this case the resistance to spreading is roughly twice the resistance to elongation. Now it is known that in the case in question the spreading is about 44 per cent of the draft. Let the draft be 4.6 inches, then the spreading is $.44 \times 4.6$, which is a little more than 2 in. From the fact that the volume of steel remains constant follows, $16 \text{ in.} \times 16 \text{ in.} \times \text{unit length} = (16 - 4.6) \times (16 + 2) \times X \times \text{unit length}$, where X is an elongation factor, and $\frac{16 + 2}{16} = 1.12$ is the lateral spreading factor. We find $X \times \frac{256}{11.4 \times 18} = 1.24$. Then $1.24 - 1 = .24$ goes into length, and $1.12 - 1 = .12$ goes into width, so that actually $\frac{.24}{.12} = 2$, as was to be expected.

Many attempts have been made to express the spreading in flat passes by single formulae. A careful search of American, English, French and German literature shows that practically all of the published

formulae are of German origin. Thus Kirchberg stated (in *Stahl und Eisen*, Oct. 15, 1903) that linear spread is equal to draft divided by angle of contact (degrees), and that it is independent of the width of the steel. Scheld (in *Stahl und Eisen*, March 9, 1910) gives this relation: linear spread =

$$\frac{\text{arc of contact "} \times \text{draft "} \times \sin(\text{angle of contact})}{\text{height after pass "}}$$

which can be easily transformed (see Fig. 5) into linear spread = $\left(\frac{B}{h}\right) \times \text{angle of contact (in radians)} \times \text{draft}$. This formula likewise supposes that the linear spreading is independent of the width of the entering section.

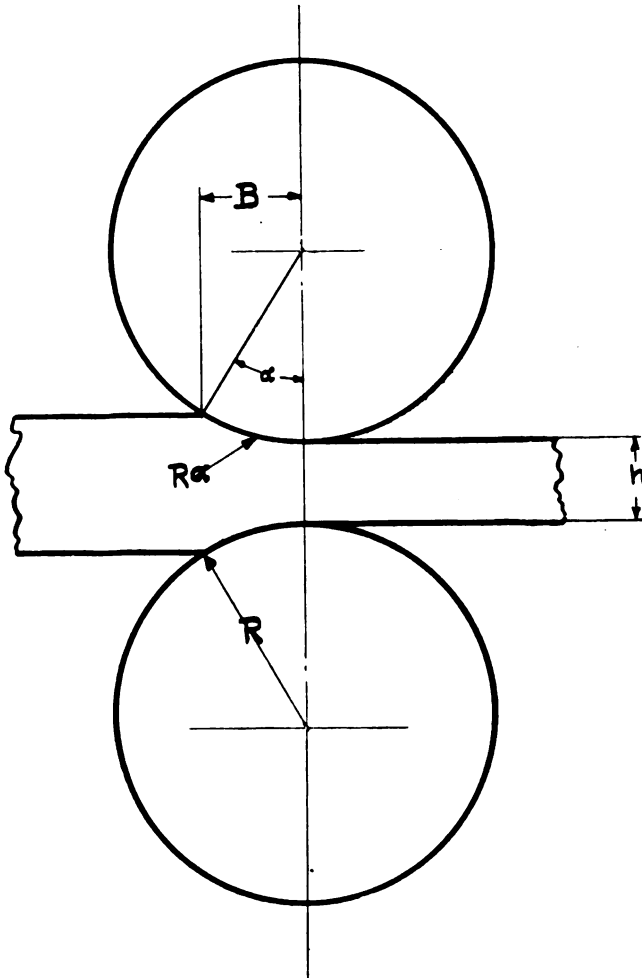


Fig. 5.—Notation for Scheld's formula for spreading.

It is quite evident that neither of the two formulae is rational, although either one will do over a narrow range of values. The danger with formulae of this sort is that they are applied outside of the range for which they hold, because the limits within which they are applicable are not given. Scheld's formula gives good results for blooming and billet mill practice.

Influence of Reduction.

The few handbooks in existence on roll design state that spreading increases 1) if the temperature of the rolled steel drops, 2) if the velocity of rolling

grows, and 3) if the rolled steel is harder. Many roll designers consider these rules as true, since they are generally considered to be based on established facts. To satisfy himself as to whether they are correct or not, Scheld made tests, rolling steel of various temperatures and hardness, and varying the speed within wide limits. (See *Stahl und Eisen*, March, 1910). The result of his tests surprised many mill men. With wide variations of temperature, velocity of rolling and hardness of steel, the lateral spreading was found to be invariably the same, for a given section, as long as the draft was kept constant. The tests were so carefully made that they cannot very well be questioned, and the problem arose to harmonize them with every-day experience of rollers and roll designers. The explanation given by Scheld is this:

1) Colder steel, 2) harder steel, and 3) faster rolling, force the rolls apart (spring them) considerably more than 4) hot steel, 5) soft steel, or 6) slow rolling. Consequently the actual draft with any one of the conditions 1, 2, or 3 is less in the earlier passes than it would be with conditions 4, 5 or 6. When the



Fig. 6.—Method of obtaining lateral spreading in flat wide passes.

steel enters the finishing pass, the draft is larger with conditions 1, 2 and 3 than otherwise. The rolls must be set closer and the final reduction becomes greater. A greater draft in the last pass means greater lateral spread, and the impression is caused that the material spreads more.

Influence of Shape of Pass.

At the beginning of the present installment men-

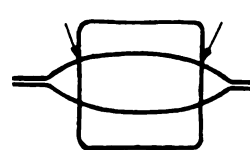


Fig. 7.—Square entering oval.



Fig. 8.—Oval entering square.

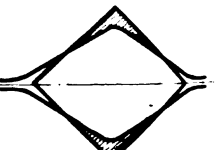


Fig. 9.—partly filled diamond pass with no spreading.

tion was made of the fact that the shape of the pass affects lateral spreading. The truth of this statement will easily be recognized from the study of a wide flat pass with added upturned corners, see Fig. 6. From previous explanations it is evident that there would be no lateral spreading at all, if the entering section were rectangular. But on account of the added thickness at both sides, the compression is greater at both sides of the plate than in the center. Lateral contraction due to elongation and lateral spreading due to compression no longer neutralize each other. The latter predominates, and the rectangular area approximately equal to the triangular excess area is added

on the side. In practice this expedient is sometimes used in order to fill a wide pass.

A similar action can be observed if a square enters an oval, see Fig. 7. Here, too, the compression is greater at the corners than it is at the center. If no other action interfered, the center would hold the sides back and would cause them to spread considerably. But the inclination of the sides tends to keep the material together in the center, (see arrow in Fig. 7), and thus partly counteracts the spreading tendency. Fig. 7 is drawn to scale, (mill pinion diameter = 16"), and shows what may be expected.

The tendency of inclined sides to keep the ma-

terial together and to prevent spreading is very apparent in Fig. 8, which shows an oval entering a square.

If in the rolling of diamonds, the rolls are pulled apart somewhat, the combination of two influences can be observed. Let a square enter a diamond in such a way that it is compressed in the central part only. Then there is absolutely no lateral spreading. First, the direction of the force is toward the center, second, the center only is elongated by compression. It pulls the sides along so that "lateral contraction" counteracts spreading. Examples of this sort are found daily in rolling mill practice.

Power House Design for Economy

By ALEXANDER DOW, President Detroit Edison Company.*

The most useful response which I can make to the invitation to join in this discussion is to give you—first—some personal opinions based on thirteen years' knowledge of big turbines, and—second—the recent costs of a steam turbine station.

The first big turbine for which I was responsible was big in its day although it would be considered small now. It was a 3,000 kilowatt vertical shaft 600-turn machine which went into commission in 1904. It was followed by three others of the same size and speed, and a fifth of the same size but higher speed, and more economical. Following these, I have had in the service of The Detroit Edison Company four 9,000 kilowatt turbines, three of 14,000 kilowatts and one of 15,000 kilowatts, all of these being of the vertical type; and three 20,000 kilowatt machines of the horizontal type. We have under contract two turbines of 30,000 kilowatts and one of 45,000 kilowatts, the latter of which is now in transit from the factory.

A word as to the vertical shaft machine. It was preeminently a reliable turbine. Its reliability earned the affection of the men who had to live with it. Its inherent limitations are those of the vertical shaft, restraining it to a low rotative speed, which means (in a large turbine) either impracticably large discs or a sacrifice of economy. If some one would discover and apply a force acting horizontally as gravity acts vertically the limitations would be removed and I believe the vertical shaft machine would continue to be the favorite of the central station operator.

My first large turbine used just twice as much steam per kilowatt-hour as does the latest one. Of course that first one is out of service long ago. It was replaced by one of the 9,000 kilowatt turbines, and its original string of boilers, rearranged with different stokers and gas

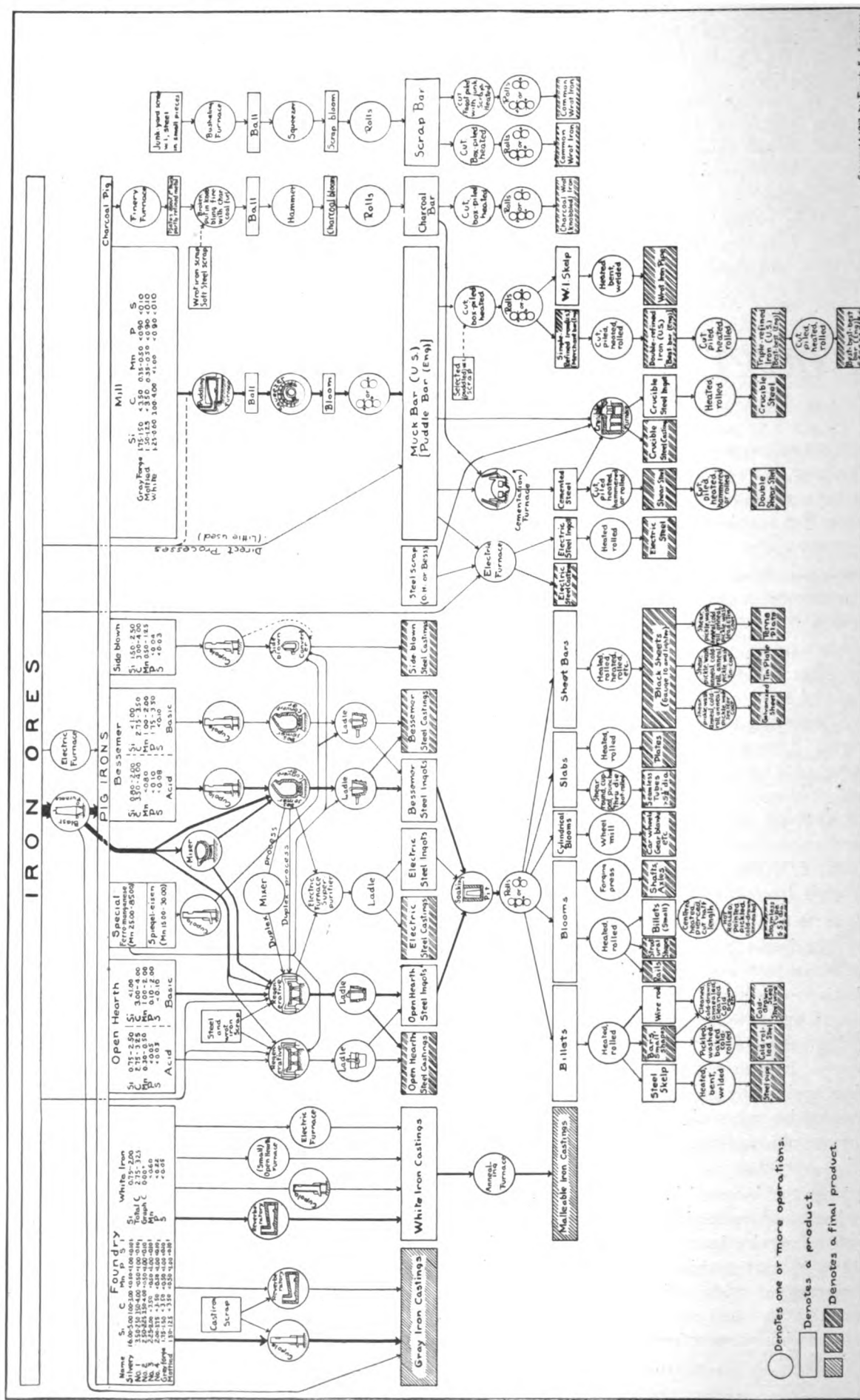
passages, serves the 9,000 kilowatt machine. The new turbine takes less steam and the boilers now make more steam. The improvement in the boiler room during the thirteen years is less spectacular but quite as useful as the improvement in the steam turbine. Unfortunately it is less known. I confirm Mr. Rice's statement that sustained boiler house efficiencies of 81 to 82 per cent are possible, economizers being used. My justification for this statement is that we have year after year a boiler house efficiency of 76 per cent, all losses by banked fires included, etc., and made without economizers.

My observation is that turbine efficiency is too often cancelled, in the total operating costs, by badly designed and badly managed boiler houses, by poor condenser practice and by neglect of station heat balance—the usual fault of heat balance being an excessive or careless use of steam auxiliaries; the less frequent fault being making a fad of electric auxiliaries.

I arrange the conditions of power house design for economy, in order of importance, as follows:

- 1.—Design your furnace and the gas passages of your boiler for the exact fuel you are going to use, or for an intelligent compromise among the different fuels which you may be compelled to use at one time or another.
- 2.—Design the condenser system so as to utilize the full possibilities of high expansion which characterize the steam turbine; but without overcooling the condensate.
- 3.—Buy a good steam turbine—remembering that it is possible to refine turbine design, in reaching for thermal efficiency, beyond the point of mechanical reliability.
- 4.—Make your heat transfer as nearly as possible a closed cycle. This requires that you consider condensate temperature, make-up water, auxiliary power, station uses of energy, furnace draft and economizers, as one all together problem; and not as several separate problems to be left separately to the purchasing agent or to the "catalogue engineer."

*From a discussion of paper read at the American Iron and Steel Institute Meeting, New York, May 25th, by Richard H. Rice, entitled "Recent Installations of Large Turbo Generators."



Graphical representation of the sequence of the various processes in the manufacture of iron and steel.

Chemical Reactions of Iron Smelting

By HENRY P. HOWLAND.*

Mr. Mathesius has presented a paper which blast furnace operators will do well to study and to put into practice. The tendency of American blast furnace men is to give too little emphasis to the technical side of their profession. While I do not agree with the author in all his conclusions, he has certainly covered the ground admirably. What I wish to do is to mention briefly and simply the more interesting points in blast furnace theory.

Let us remember that practically all of the scale, scrap, iron and steel in the world to-day had as its first step, to be produced in the Blast Furnace. All of our principal iron ores are a chemical combination of iron and oxygen. The function of the Blast Furnace is to deprive the ore of its oxygen and then to melt the remaining iron. You will note that Mr. Mathesius' article deals entirely with the reactions between the carbon of the coke on the one hand and the oxygen of either the air or the ore on the other hand. It is impossible for us to change the quality of the oxygen in either the air or the ore. We have, however, learned by sad experience that we can change both the quantity and quality of the carbon in the coke.

The existence of the blast furnace depends upon the simple fact that a large enclosed body of coke cannot be burned by air to CO_2 (carbon dioxide). To state it another way, if we have a furnace full of coke only, the gas coming from the furnace top would contain carbon gas, only in the form of CO (Carbon Monoxide). This CO is in search of another atom of oxygen and it is the business of the blast furnace to satisfy this desire by introducing Iron Oxide Fe_2O_3 . As the iron oxide introduced at the furnace top works downward through the rising current of CO gas, most of it loses its oxygen, thus becoming Fe ready to be melted in the hearth. This reduction of Fe_2O_3 by CO is termed "indirect reduction."

The problem of blast furnace efficiency is to bring as much as possible of the iron ore and CO into intimate contact. This results in a minimum of CO leaving the furnace without having met some of the iron ore and also in a minimum of the iron ore getting down into the furnace hearth without having lost its oxygen to the CO .

When the iron oxide does get down into the hearth there is only one thing that can happen, namely, the oxygen must be removed by means of unburned carbon, or as we term it, "direct reduction."

Mr. Mathesius has brought out very clearly the relative values of the indirect and direct reduction with

regard to both the amount of carbon required and the heat consumed. The amount of carbon required depends upon the way the equations of reduction are written. There is some difference of opinion along this line and I am one of those who would write the equations differently from Mr. Mathesius. We do agree, however, upon the positive value of direct reduction as stated by him.

The fact that the direct reduction of iron oxide by carbon takes place in the hearth and that this reduction absorbs a great amount of heat tends to make the hearth cold. It is interesting to note in this connection the similarity between the human being and the blast furnace. A furnace with hot top and a cold hearth is exactly in the same need of treatment as a man a hot head and cold feet; in other words, we have the well-known term—a sick furnace. The treatment consists in getting the furnace hearth hot, either by using hotter air blast or additional coke, or better still, a better quality of coke. To quote Mr. Mathesius "the limit to which this direct reduction can be carried on depends on the ability to offset the resultant heat deficit in the hearth by higher blast temperature." I would state this differently, by placing more emphasis upon the quality of coke. In other words, unless we have a coke of good quality it is practically useless to attempt to supply the heat loss, due to direct reduction by the application of high blast heats.

A good coke will burn instantaneously to CO , creating the heat in the hearth where it is needed. The gases generated in the hearth require but a few seconds to pass through and out of the furnace and unless the CO is made in the first fraction of a second, the heat may be produced where it is almost worse than useless.

Mr. Mathesius illustrates the value of his theories in general and the application of high blast heats in particular, by citing the remarkable record made at South Works for the year 1916—over 2,000,000 tons of iron with an average coke consumption of 1854 pounds of coke per ton of iron—certainly a most wonderfully remarkable record.

At the plant of the Wisconsin Steel Works we have a furnace which has given remarkable results, though on lower blast heats. It is the work of this furnace that has convinced me of the supreme value of a highly combustible coke.

The furnace was blown in in August, 1914; the production is as follows:

	Gross Tons
Monthly average	17,300
Year 1915	211,700
Year 1916	208,100
Total for the Blast to May 1st, 1917	553,000

The coke per ton of iron for the blast to May 1st,

* Discussion of paper read by Walter Mathesius before the American Iron and Steel Institute meeting, at New York, May 5th.

1917 as actually charged to the furnace, based upon railroad scale weights at the ovens several hundred miles away, is 1703 pounds. Included in this is about 3 per cent screened out at the pockets, but charged to the furnace.

As Mr. Mathesius points out, the prime qualifications of a good coke are—First, Its ability to resist the destructive action of CO_2 in the top of the furnace and—Second, Its ability to burn instantaneously in the hearth. It so happens that these two requirements are as he also points out, diametrically opposed. All the coke burned by air in the hearth is first burned to CO_2 but immediately broken up into CO by the reaction

$\text{CO}_2 + \text{C} = 2 \text{CO}$, due to the intense heat of the hearth. In other words, for a good coke we require one which as it works its way down through the furnace will refuse to have anything to do with CO_2 , but when it finally reaches the hot hearth it will immediately be consumed by CO_2 . A good deal to ask of an ordinary piece of coke. However, this is the kind of coke we have been producing at many of our coke plants in the past few years.

The advance in blast furnace practice in recent years is, a coke conforming to the requirements stated above and—Secondarily, better furnace lines.

Turbo-Generator Installation Discussion

By D. S. JACOBUS.*

Mr. Rice's comparison of the results obtainable with large steam turbines and gas engines is a most interesting one. He shows that the thermal efficiencies of the two types of prime movers will be about the same for the power plant considered, where blast furnace gas is used for fuel, together with coal which is used in small amounts during occasional deficiencies of gas supply. When it comes to figuring the total charges for the plant per year, the balance is strikingly in favor of the steam turbine, as his figures indicate that the total charges for the steam turbine plant would be about one-half that for the gas engine plant with its auxiliary steam plant.

Mr. Rice states that by using the most modern equipment of boilers, superheaters and economizers, with gas which is passed through primary washers, that an efficiency of 81 per cent can be obtained. This figure may be reached with the proper equipment and the best sort of operation for a continuous load.

To obtain the best efficiencies with blast furnace gas there must be but little excess air supplied for combustion and the gas must be completely burned before the products of combustion pass upward between the boiler tubes. To accomplish this there must be a sufficient furnace volume so disposed that there will be a proper path of travel for the flames, and the gas burners must be arranged to give the proper proportions of air and gas and the proper mingling of the air and gas. Recent developments with burners arranged so as to bring the pressure of the gas up to the outlet and so designed as to give an intimate mixture of the air and gas have before entering the furnace shown that higher furnace temperatures can be maintained than in the older practice and that the gas can be burned with a shorter flame than in certain of the older forms of gas

burners. Higher furnace temperatures and the ability to burn the gas within a given furnace volume and the proper design of the boiler and its economizer makes it possible to obtain the efficiency given by Mr. Rice.

In the comparisons made in the paper the gas engine plant includes a reserve steam plant for carrying a portion of the load in case of emergencies. It would be interesting from a thermodynamic standpoint to compare the efficiency obtainable from the best gas engine plant with no steam reserve plant with that obtainable from the best modern steam turbine plant, the efficiencies being based on the heat in the gas used by the gas engines and on the heat in the coal or gas used by the steam turbine plant. It would also be interesting to make a comparison of the heat of combustion of the coal, the coal in one case being gasified in producers and the gas supplied to the gas engines, and in the other burned under the boilers. Such a comparison would not be a commercial one, as all fixed and operating charges would be eliminated, and further it would not form the basis of a fair comparison as the reserve steam plant is necessary to secure the same approximate degree of reliability for the gas engine plant as for the steam turbine plant, and the fuel required for the reserve steam plant should be included. The comparison nevertheless would give interesting data respecting the thermodynamic possibilities apart from reliability and fixed charges. It would appear that the results will indicate a somewhat greater coal consumption for a gas engine plant where the coal is gasified in producers than for a steam turbine plant, which is contrary to the ideas of many. It would add to the value of the paper if figures could be given by Mr. Rice to cover these cases.

Mr. Rice speaks of possibilities through combined gas engine and steam turbine plants, pointing out that a steam turbine plant operated by the waste heat from a gas engine involves such a larger expense in comparison with the increase of power as to make it unat-

(Continued on page 330)

*From a discussion of paper read at the American Iron and Steel Institute Meeting, New York, May 25th, by Richard H. Rice, entitled "Recent Installations of Large Turbo Generators."

PRODUCTION TOPICS

PROBLEMS IN USE OF LIQUID FERROMANGANESE.

In a communication from Robert J. Anderson, of Cleveland, O., to the Franklin Institute of Philadelphia, which is printed in the May issue of the Journal of the Franklin Institute, and of which a reprint has just been issued for more general circulation, the author reviews the recent dilemma of the steel industry during the early period of the European war in the matter of ferromanganese supply. The author, in conclusion remarks that, in view of the utter dependability of steel makers upon foreign sources for their manganese supplies, it is little short of surprising that more time has not been spent upon the subject of substitute deoxidizers or even on the matter of conserving the available manganese supply. When spiegeleisen, the low-percentage manganese alloy, is melted in cupolas, the large clouds of red smoke constantly issuing from the cupola tops indicate the utter extravagance of such a method. For melting the high-percentage alloy, the cupola is totally out of consideration. Various furnaces, fired by coke, coal, gas, or oil, have been tried for melting manganese alloys for liquid addition

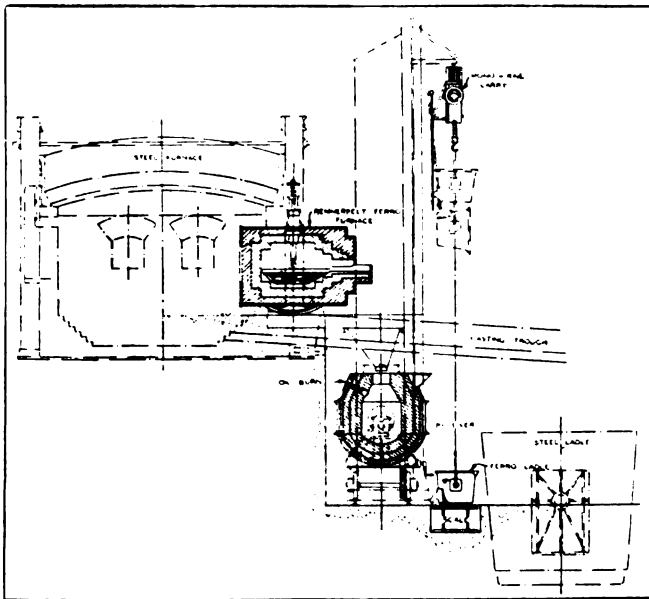


Fig. 1.—Rennerfelt melting furnace and scheme for large plant making heavy heats. (After Sahlin).

without satisfactory results. The standard method of adding ferromanganese (i. e., the high percentage alloy) has been to break the alloy up into lumps and shovel it in the solid state; in many European works the alloy is preheated red hot before adding. However, the experience of practice has shown the extravagance of this method also, because the loss in manganese totals from 20 to 35 per cent from volatilization. If this could be recovered it would represent a

* Sahlin, Alex., "The Use of Liquid Ferromanganese in the Steel Processes," Jour. Iron and Steel Inst., 1914, No. 2, p. 213 et seq.

† McKee, W. S., "Making Manganese Steel Castings," a paper at the Cleveland 1916 meeting of the American Foundrymen's Association.

‡ Boylston, H. M., "Investigation of the Relative Merits of Various Agents for the Deoxidation of Steel," Carnegie Scholarship Memoirs of the Iron and Steel Institute, vol. 7, 1916, p. 102.

yearly saving, in a plant making 300,000 tons of steel per annum, of about \$26,000, figuring ferromanganese at \$55 a ton. At the price paid for ferromanganese in the past two years, the saving would be a great deal more. Naturally, whether it would pay to make this saving would depend upon the cost of so doing.

Among others, Alex Sahlin, of Brussels, has prominently pointed out how melting ferromanganese in the electric furnace is both practical and economical.* No practical method for melting was available until the advent of the electric furnace, but now a number of plants in Europe have installed ferromanganese melting furnaces. Heroult, Girod, Nathusius, and Keller arc furnaces, as well as the Roechling-Rodenhauer induction furnace, are used. The cost of electric current for operating constitutes the principal expense item. Irrespective of the working of the method, it is stated on good authority that worth-while savings can be effected, and those interested can refer to the account by Sahlin. The Rennerfelt furnace, brought out in 1913 by Ivar Rennerfelt, has proved particularly applicable for ferromanganese melting. Using this furnace, the layout in Fig. 1 is recommended for large steel works making heavy heats. Where high-grade or special steel is being made, and cost is a minor consideration, as in the manufacture of manganese steel castings,† the ferromanganese is melted in crucibles or in small, specially-designed reverberatory furnaces. This method of procedure would not do for general work.

Summing up, the author remarks that it appears, in the light of the facts presented in the foregoing, that the manganese situation is one of serious importance—one that warrants thoughtful consideration on the part of those interested in the subject. The possibility of metallurgical science discovering a substitute deoxidizer which will take the place of manganese, either in whole or in part, appears to be an alluring one. Naturally, any attempt at such an endeavor will call for a large amount of labor on the part of many men, and it is not to be supposed that the final solution of the problem will be effected in any short time. The matter of obtaining suitable coöperation with steel makers for the use of their plants so that experiments may be carried out on a scale commensurate with that of practice is one that will have to be taken care of by research men who hope to contribute in large measure to any progress along this line. Steel works laboratories have an opportunity before them, if they have not already grasped it—and they apparently have not, if published data can be any criterion. A recent investigation‡ carried out in this country appears to be the first well-defined attempt in this direction.

ADDITION TO THE SPEER CARBON PLANT.

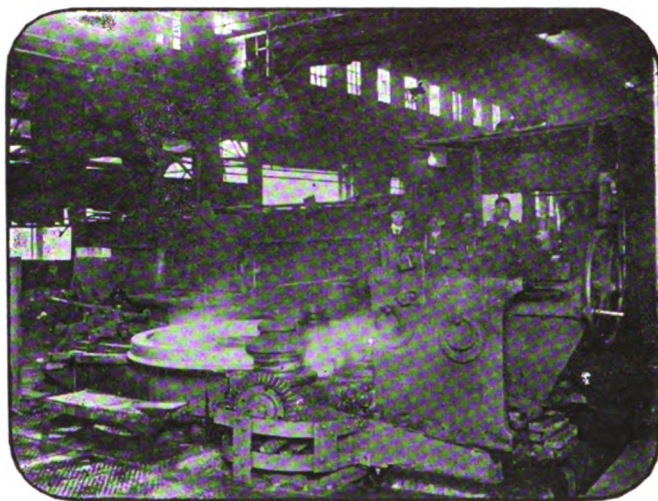
Work has already been started on the first unit of a new factory that will form an immense addition to the present large plant of the Speer Carbon Company at St. Marys, Pennsylvania, and which, when entirely completed, will involve the expenditure of approximately \$500,000 for additional land, buildings, machinery, equipment and general improvements.

The first building, which will be devoted exclusively to the manufacture of the larger sized carbon electrodes for electric furnaces will be 100 x 168 feet in size and constructed entirely of brick, concrete and steel.

THE TIRE MILL IN ARMAMENT MAKING.

In concluding his paper on "The Relative merits of Forming Steel by Pressing, Hammering and Rolling", before the May meeting of the American Iron and Steel Institute (which was abstracted in the June issue of THE BLAST FURNACE AND STEEL PLANT), John Lyman Cox gives these details of the employment of a tire mill on armament work:

There remains another form of the rolling mill which we have not considered—the tire mill. The early schemes for our coast defense called for a large number of 12-in. mortars consisting of a cast iron body reinforced by steel hoops. As the hoops were of some 3 ft. inside diameter and there was no forge in the country equipped for making them long, which could be easily rolled in a tire mill.



Galloway tire mill.

These hoops were manufactured by cutting from a 20-in. round ingot blocks of the proper weight, upsetting and punching them under a steam hammer, breaking them on the horn of an anvil, and then rolling them to diameter in the tire mill, which can produce rings approximately 20 in. in width. Every step of the operation was in the direction of the expansion of the diameter. Owing to the forgings being without end they could be chilled rapidly as they neared final dimensions and they almost always filled the specifications on the first submission, rarely requiring retreatment. On one order, out of 305 test bars broken from the hoops only two, showing small defects, failed to give the requirements and then extra bars met them.

CARBON-MONOXIDE IN THE BLAST FURNACE.

In connection with his most comprehensive paper on "Chemical Reactions in Iron Smelting," before the May meeting of the Iron and Steel Institute in New York (published in abstract in last month's issue of the BLAST FURNACE AND STEEL PLANT, Walter Mathesius, of the Illinois Steel Company, devoted "a word in closing" to a phase of modern American furnace practice which, he admitted, appeared in modern furnaces "only occasionally to any extended degree"—that is, the decomposition of carbon monoxide according to the equation $2CO = C + CO_2$. The author said:

As the speed of this reaction is comparatively low, on account of the existing ratio of quantities involved, and since the zone of temperatures within which it can take place is limited to approximately from 400 deg. to 600 deg. C., the extent of this reaction is, as a rule, slight. Theoretically it must be classed as economical, being exactly the reverse from "premature combustion." However, in practice, when this reaction takes place to any considerable degree, serious difficulties are encountered which make it extremely unde-

sirable. The resulting carbon is deposited on the ores in a very finely divided form and interferes with their permeability to the gases, clogging the voids and causing a swelling of the charges, scaffold formation and all the serious troubles which follow.

When fine Mesaba ores were first used in larger percentages such difficulties due to excessive carbon deposition were experienced more frequently. With furnace lines poorly suited for the smelting of these fine ores, particularly with the flat bosh angles then in use, irregular working of the furnace with protracted periods of hanging were nothing exceptional. The movement of the furnace charges being brought to a standstill for considerable periods of time, a much larger percentage of the materials in the upper part of the furnace stack was heated to a temperature where decomposition of carbon monoxide could take place, with a corresponding increase in the extent of this reaction as the result. Since then, however, furnace lines have been improved to such an extent as to make operating difficulties from this source a rare exception in Mesaba practice.

It has been observed, too, that a high percentage of hydrogen is often present when carbon is deposited in this manner. The reducing power of hydrogen relative to that of carbon monoxide increases with falling temperatures, and it is reasoned that, with a high percentage of the former, metallic iron in finely divided form is reduced from the ores at exceptionally low temperatures; this metallic iron then acts as a catalytic agent which greatly increases the reacting speed of the decomposition of carbon monoxide.

Excessive hydrogen in the top gases to an extent necessary to bring about such a condition is generally the result of defective apparatus, such as leaky hot-blast valves, tuyeres and bosh plates. If this be the case, the undesirable deposition of carbon can be overcome by removing the source of the hydrogen.

LARGE BEEHIVE OUTPUT IN 1916.

Beehive coke production in the United States in 1916 was the largest ever recorded. Official figures of the U. S. Geological Survey place the output at 35,464,224 tons, valued at \$95,468,127. This is an increase of 7,955,969 tons, or 29 per cent, over that of 1915, and larger by \$38,522,584 or nearly 68 per cent in value. The average value of the coal used in 1916 was \$1.26 per ton, an increase of 21c. over 1915, and the average value of the coke last year was \$2.69 per ton, an increase of 62c. There were 65,605 active beehive ovens in 1916, as against 48,985 in 1915, an increase of 16,620. The idle ovens were 25,876, as compared with 44,125 in 1915. Abandoned ovens were 2265, of which nearly 1800 were in Pennsylvania. No new ovens were built.

Turbo-Generator Installation Discussion.

(Continued from Page 326)

tractive under existing conditions. Should the cost of fuel be great enough a plant of the sort might be commercially practicable, but would seem that this will not be the case for a long time to come.

In the engine we obtain high efficiencies at the high temperature end of the cycle but are unable to utilize the low temperature end. In the steam turbine with modern condensing apparatus the low temperature end of the cycle is utilized to the fullest extent. It would therefore appear that there are great possibilities in combining the two. On working out an actual case it will be found that the work of the steam turbine would be comparatively small, amounting to, say 10 per cent of that of the gas engine, and it can be seen that the large amount of additional expense and complication involved would offset the saving in the cost of fuel unless the fuel is comparatively expensive.

Causes for High Electrode Consumption in Electric Furnace Practice.

One of the largest cost items in the manufacture of steel by the electric furnace comes from electrode, or carbon consumption. The troubles are not only due to the operator, but also to the manufacturer.

The first discussion naturally is the quality of the carbons. A careless operator may be the cause of high carbon consumption but even the most careful operator can often directly trace his trouble to the defects in the manufacture of the carbons themselves. A summary of these defects are:

- a—Hard or soft carbons
- b—Bent carbons
- c—Too large
- e—Patterns of screws not set together.
- d—Too small
- f—Not square on ends
- g—Carbons swell
- h—Carbons off center.

The softness or hardness of carbons is very important. This is entirely up to the maker and is governed by the material put into the carbons themselves, and the method of manufacture. Both are equally important for although extreme hardness is not desired, the carbon must be hard enough and strong enough to stand some abuse. In the first place, carbons 17 inches or over in diameter, are just a little awkward to easily handle and therefore even with the greatest care they may receive some pretty hard knocks at times.

It is not infrequent in starting up with square ends on the carbons and irregular surface of the charge to have the carbons break off when the automatic control brings them down on the charge. If the ends are known to be square the charge should be leveled if possible underneath. This is not always possible due to the character of the stock.

Carbons that are too soft will give trouble at all times, in putting new carbons on, in starting a heat, in the middle of a heat, or even at the end of a heat when tilting the furnace. In putting new carbons on, even the most careful operator may break them in handling them; in starting a heat automatic control may break them off leaving them deeply burned in the charge and thus giving extreme trouble in getting them out; in the middle of the heat there is always the danger of falling in the bath and raising the carbon in the steel far over the required limit; at the end of the heat when tilting the furnace just the weight of the carbons themselves often breaks them off at the screw and at times their removal from the empty furnace is very aggravating.

It is not infrequent to receive bent carbons with large shipments. Such a carbon cannot be screwed tightly. This gives rise to a bad joint. In raising and lowering the electrode holders sometimes such a carbon will bind. It will give trouble in making the joint with the previous carbon and the following.

Perhaps no one thing is more aggravating than to have the carbons vary in size. Some are too small, some are too large. In putting on a new carbon with the roof very hot, it is very trying to spend from one to two hours trying to fit a carbon that is too big. Often even when the holder has been opened as far as possible still the carbon cannot be made to go into the holder and not infrequently they must be taken down again altogether. As long as this big carbon is in the holder it will cause trouble every time the holder has to be raised or lowered. Carbons that are too small are no less troublesome. After the holder has heated it may expand, the carbon dropping into the furnace and the chances are it will break off and ruin a heat, or at best

give the operator a very hard, hot job pulling it out of the furnace.

Copper liners have been hung inside the holder to grip carbons that are too small but this is extremely bad practice since an arc may be created between the holder and the carbon on either side of the liners.

It is not infrequent to get a positive example of poor workmanship or else poor inspection before the carbon leaves the manufacturer. For example screws have been received where the patterns have not matched and the couplings could not be screwed into the female of the carbon. The threads instead of being smooth and rounded are irregular due to the lax matching of the patterns. This may hinder the making of a tight joint, later developing a hot joint or even causing the screw to burn through entirely. It not infrequently happens that arcs develop on account of bad screws and carbons practically unused go to the scrap pile.

Occasionally carbons are received that are not square on the ends and no matter how tightly the carbons are screwed together the joint remains defective. In this case, in fact in all cases the filler between the carbon and screw should not be used sparingly. Both should be well covered and the mixture made thick enough to form a good solid joint. If the filler is not thick in the opening between the two carbons an arc will soon develop and it will not be long before the screw is burned through and the lower carbon will drop into the bath or into the furnace when tilting to pour the heat. At best the damage will be a red hot joint and this will help to burn up the lower carbon.

It is not infrequent that a carbon will be received that will swell considerably after it has been put into use. This expansion is extremely annoying since the carbon sticks tight in the holder and raising or lowering it is difficult without breaking.

One of the most aggravating of all carbon troubles is when the holes are off center. This makes it almost impossible to get the holder above the joint. Too much care cannot be taken in cementing these holes for it is exasperating to spend an hour or even two hours on a hot roof trying to get such a carbon through the holder. Even with the greatest care carbons have been broken off at the screws in trying to get off centered carbons through the holder.

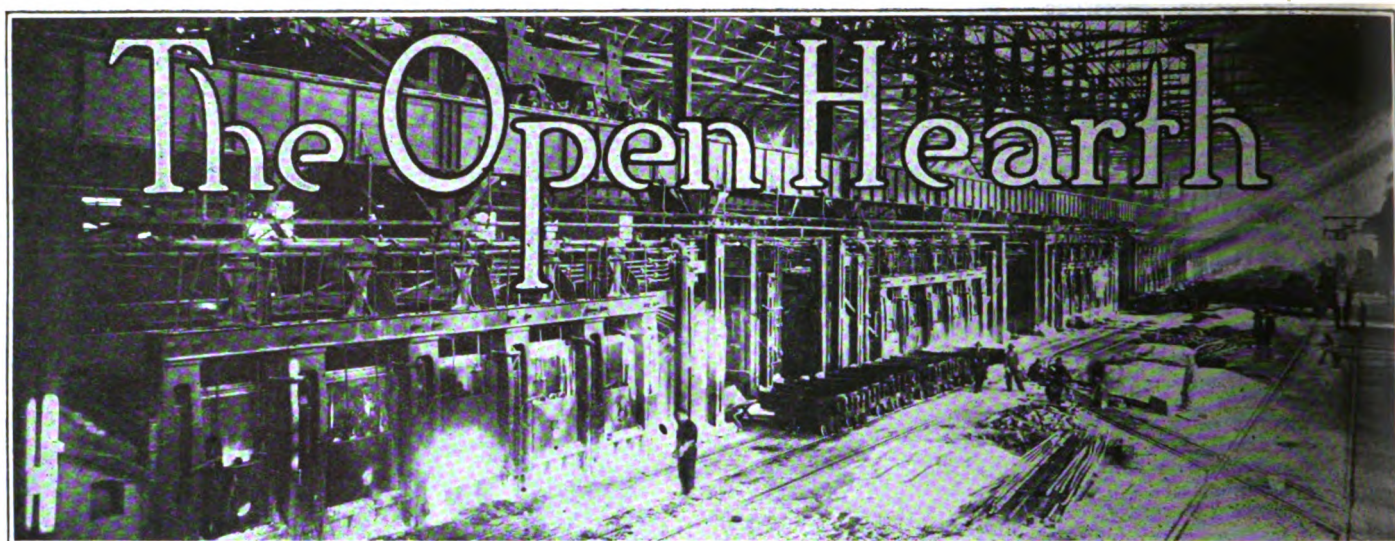
By-Product Coke Oven Installation.

Actual construction of twenty-four new Semet-Solvay by-product coke ovens was started recently at the plant of the Chattanooga Gas & Coal Products Company, marking the beginning of an improvement and expansion that, it is claimed, will put the Chattanooga concern in the front rank of by-product plants.

Contract for the ovens was let to the Semet-Solvay company, of Syracuse, N. Y., and a corps of expert construction engineers immediately dispatched to take charge of the work. It is hoped that the work will be completed in six months, and every energy and effort is being bent towards that end.

Slightly in excess of half a million dollars will be expended in completing the project, exclusive of rebuilding the twelve Roberts ovens which now comprise the plant. It is planned to undertake this rebuilding after the new Solvay plant is completed and in operation.

The new ovens will have a capacity of 10,000 tons of high-grade coke monthly and will produce 4,000,000 feet of gas, half of which will be used in operating the ovens and half of which will be sold. A corresponding increase in the output of other by-products will occur, with perhaps a greater percentage of recovery, due to the improved type of oven in



Mr. G. E. Land, recently with the advertising department of the National Tube Company, has been appointed advertising manager of the Blaw Knox Company, Pittsburgh, Pa.

V V

Oscar U. Cook, for some years chief inspector at the upper and lower mills of the Carnegie Steel Company, Youngstown, Ohio, has been appointed metallurgical engineer for the Tennessee Coal, Iron & Railway Company, Birmingham, Ala.

V V

Keith R. Rodney, for many years connected with the Midvale Steel Company, and for the past two years supervisor of heat treating for the Winchester Repeating Arms Company, New Haven, has recently joined the staff of the Bullard Machine Tool Company, Bridgeport, Conn., as metallurgist and advisor in the selection and treatment of steels.

V V

James H. Morris, who has been auditor of the William Tod Company, Youngstown, Ohio, has just been made assistant auditor of the Brier Hill Steel Company.

V V

Capt. Elmer K. Hiles has been called into active service of the Fifth Engineers Regiment and has reported for duty. Captain Hiles is secretary of the Engineers' Society of Western Pennsylvania and began training for the service last summer at Plattsburg, N. Y., where he made a splendid record.

V V

Robert Radford, secretary and assistant treasurer of the Standard Steel Works Company, Philadelphia, has been recently elected president of the Southwark Foundry & Machine Company of that city.

V V

F. C. Smink, president of the Reading Iron Company, has been elected president of the new Blandon Rolling Mills Company recently organized to operate the old mill at Blandon, Pa.

V V

H. A. Whitaker, of the Cambria Steel Company on May 1 began his new duties as general superintendent of the Worth Brothers Company plant, Coatesville, Pa., now controlled by the Cambria Company. Harry I. Schotter, his predecessor, resigned.

V V

The Society of Ohio Safety Engineers, with headquarters at Columbus, has elected the following officers for the ensuing year: President, C. E. Pettibone, Pickards Mather & Co., Cleveland; vice-president, J. M. Woltz, Youngstown

Sheet and Tube Company, Youngstown; secretary-treasurer, E. R. Rose, Republic Iron and Steel Company, Youngstown, and assistant treasurer, G. F. Hodgson, Republic Rubber Company, Youngstown.

V V

J. S. Fraser, superintendent of blast furnaces of the Pittsburgh Steel Company, has been appointed superintendent of furnaces and steel works, effective June 1. H. R. Shick has been made blast furnace superintendent, with Mr. Callaway as assistant. Mr. Shick formerly was assistant superintendent of furnaces.

V V

E. T. Sproull has been advanced to the general management of sales of the Trumbull Steel Company, Warren, O., succeeding A. N. Flora, who recently was elected vice president of the company. Mr. Flora also was elected to the board of directors, succeeding D. W. Kerr, who resigned after purchasing the interest of the Trumbull Steel Company in the Fort Smith Spelter Company, Fort Smith, Ark.

V V

W. W. Lyle, formerly with the Jones & Laughlin Steel Company, Pittsburgh, is superintendent of the rod and blooming mills of the Keystone Steel & Wire Company, Peoria, Ill.

V V

I. S. Fouse, formerly associated with the Standard Steel Car Company, Pittsburgh, with works at Butler, Pa., now is general manager of the Allegheny Foundry & Machine Company, Glassmere, Pa.

V V

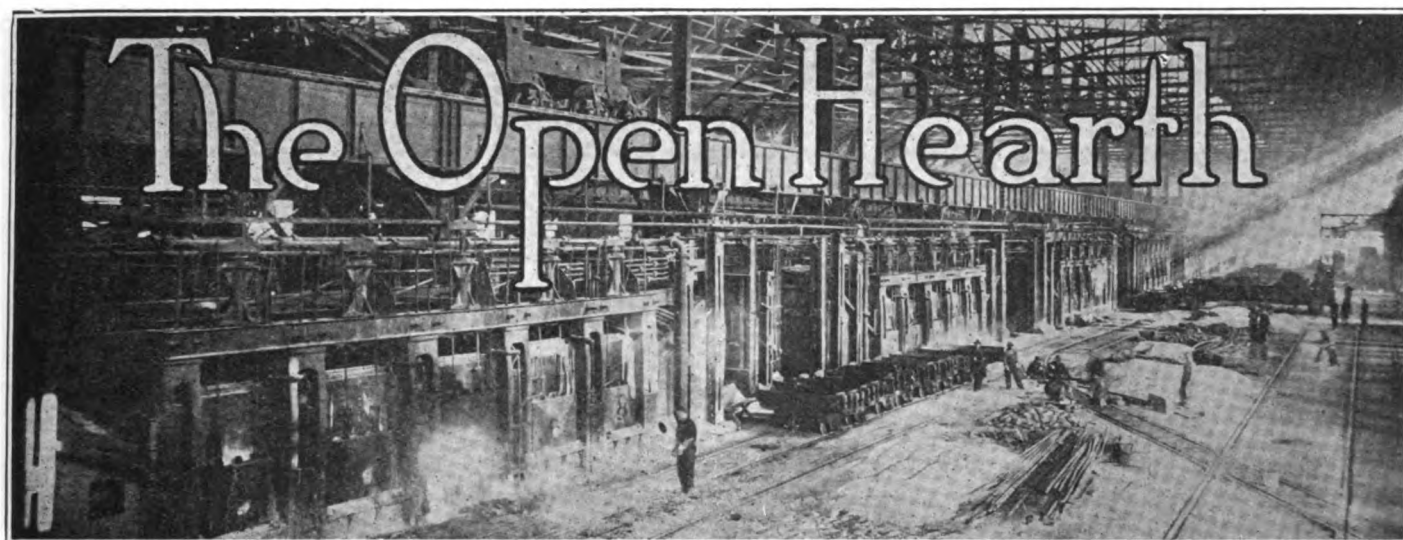
Thomas Morrison, Pittsburgh, director of the United States Steel Corporation, and Charles Hayden, of Hayden, Stone & Co., have been chosen directors of the International Nickel Company, to complete the terms of Col. R. M. Thompson and S. H. P. Bell. W. T. Graham succeeds Col. Thompson on the executive committee.

V V

William Hamlin Childs, president of the Barrett Company, 17 Battery place, New York, has been elected trustee of Syracuse university.

V V

Harry C. Baughman formerly with the Algoma Steel Company as assistant superintendent of the open hearth and duplexing department, is now connected with the Bethlehem Steel Company, Bethlehem, Pa., as assistant open hearth superintendent and in charge of the bessemer department.



The following have been elected to the waiting list for membership to the American Iron and Steel Institute:

Leonard Colton Hanna, Jr., Cleveland, Ohio, M. A. Hanna and Company; James M. Milliken, Philadelphia, Pa., Auditor, The Midvale Steel Company; William E. Marseilles, 30 Church Street, New York City, Engineer, with Latrobe Steel Company, Ill., Steel Company, and Paul Herault; Frederick C. Yeates, Philadelphia, Pa., Purchasing Agent, The Midvale Steel Company; Turner D. Moorhead, Sharpsburg, Pa., Vice President and Treasurer, Moorhead Bros. & Company, Inc.; Arnold A. Schneider, Pittsburgh, Pa., Raw Material Dept., Midvale Steel and Ordnance Company; Samuel Sigourney Wales, Pittsburgh, Pa., Electrical Engineering, Carnegie Steel Company; Charles R. Holzworth, West Middlesex, Pa., Gen. Supt., The Ella Furnace Company, and The Claire Furnace Company; A. T. Enlow, Hamilton, Ontario, Canada, President, Dominion Sheet Metal Company, Ltd.; Arch Quarrier Moffat, Wheeling, W. Va., Manager of Sales, Whitaker-Glessner Compy; Lloyd Booth, Warren, Ohio, Treasurer, The Trumbull Steel Company; Arthur Austin Clement, Chicago, Illinois, President, American Wire Fence Company; Everitt D. Graff, Chicago, Illinois, Asst. to Vice President, Joseph T. Ryerson & Son; F. A. Assmann, 25 Broad St., New York City, Chairman, Executive Committee, Standard Tinplate Company; Benjamin Wolhaupter, 61 Broadway, New York City, Vice President, The Rail Joint Company; Edwin Chapin Witherby, Syracuse, New York, Vice Pres., Semet-Solvay Company; Mark Workman, President, Dominion Steel Corporation, Ltd.; Richard D. Chapman, High Bridge, N. J., General Sales Manager, Taylor Wharton Iron & Steel Company; Harry Eugene Brubaker, Shelby, Ohio, Asst. Gen. Mgr. & Gen. Supt., Ohio Seamless Tube Company; F. E. Dussel, Alliance, Ohio, Secretary & Treasurer, The Transue & Williams Steel Forging Corporation; O. F. Transue, Alliance, Ohio, President, The Transue & Williams Steel Forging Corporation; J. E. N. Hume, Schenectady, New York, Commercial Engineer, General Electric Company; Samuel Northrup Castle, 120 Broadway, New York City, Sales Dept., General Electric Company, Expert Electric Steel Furnace; Edgar D. Baker, Woolworth Bldg, New York City, Purchasing Agent, American Steel Export Company; Robert M. Bird, South Bethlehem, Pa., Supt. Rolling Mills, Lehigh Plant Bethlehem Steel Company; W. Robert Shimer, South Bethlehem, Pa., Metallurgist, Bethlehem Steel Company; Charles S. Vought, Woolworth Building, New York City, Asst. Gen. Mgr. Sales, American Steel Export Company; A. W. Alexander, Philadelphia, Pa., Standard Steel Works Company; Jos. W. Donner, Buffalo, New York, Donner Steel Company, Inc.

W. W. Hall, who recently resigned as Pittsburgh manager of the Republic Iron & Steel Company, Youngstown, to become identified with the Columbia Steel & Shafting Co., Pittsburgh, has been made assistant general manager of that company.

V V

Arthur F. Braid has assumed the duties of metallurgical engineer in charge of metal sales for the Goldschmidt Thermit Company of Jersey City, N. J. He succeeds D. Brown, who has joined the officers' reserve corps at Plattsburg and probably will continue with the army.

V V

H. M. Roche, formerly in charge of the Mt. Hope, N. J., mines of the Empire Steel & Iron Company, has been appointed superintendent of mines for the Wharton Steel Company at Hibernia, N. J., effective July 1. Preparations now are being made to pump out the Hibernia mine and again put it in operation.

V V

Walter A. Zelnicker Supply Company, in Saint Louis, announce the recent appointment of Mr. Karl W. Bock, as Manager.

V V

W. H. Geesman formerly blast furnace superintendent at Gary, Ind., is now general superintendent of the Brier Hill Steel Company, Youngstown, Ohio.

V V

Mr. G. E. Brenholtz has resigned as head roller of the Minnesota Steel Company, Duluth Minnesota, to accept a similar position with the Forged Steel Wheel Company, Butler, Penna.

V V

W. B. Skinkle formerly with Julian Kennedy, is now assistant mechanical engineer, with the Carnegie Steel Company, at the Schoen plant.

V V

The Walter A. Zelnicker Supply Company, announce that they have secured the services of Mr. W. H. Dayton, as City Salesman.

V V

J. E. Thropp, Jr., for some time associated with E. J. Lavino & Company, of Philadelphia,—first as superintendent of the blast furnace at Sheridan, Pa., and at present as superintendent of the furnace at Marietta, Pa., which is being rebuilt; has resigned.

V V

A. A. Keally, manager of the Sharon Steel Hoop Company is now located at the Detroit office of that concern.

Some Pointers on By-Product Coke Oven Operations

Looking backward over the years consumed in bringing the coke oven to its present stage of development in America, there are some events which stand out pre-eminently. The first of these dates back to 1906. In that year the United States Steel Corporation was brought face to face with the necessity of formulating a definite policy as to its coke supply, and appointed a committee to study beehive coking and by-product coking and to make a recommendation to the company. The advice of this committee was quickly acted upon by the corporation in the decision to build a by-product oven plant at Joilet, Ill., in connection with the blast furnace and steel plant of the Illinois Steel Company, and to build that type of oven which they had found to give the most efficient results in European countries.

This plant was so successful that additional plants were built without delay.

The second event was the selection of silica material for one of the oven batteries at Joilet. The value of the silica in this connection is due to four characteristics.

- 1—The conductivity at high temperatures is superior to that of clay brick.
- 2—The fusing or softening temperature is much higher than that of fireclay.
- 3—The action under heat may be calculated with scientific exactness, due to its practically constant composition.
- 4—The expansion and contraction of silica material between 2,000 and 2,600 deg. Fahr., is practically negligible, so that when the material has once been heated to within this temperature range (under which condition the coking operations are conducted) no further appreciable movement takes place.

The third event was the realization that with uniform heat distribution in the ovens and with the use of silicate material much higher heats and consequent higher coking velocities could be employed, and, further, that, with the lower coking periods, higher volatile coals could be used, with increased yields of by-products and equally satisfactory coke.

The effect on the products can best be shown by reference to the following table:

Yields of By-Products Per Ton of Coke.

	Coal Mixture A 80% low volatile 20% high volatile	Coal Mixture B 100 % high volatile
Tar	6.5 gal.	13.5 gal.
Ammonium sulphate	23.3 lbs.	38.0 lbs.
Surplus gas (debenzolized) ..	7,500 cu. ft.	10,000 cu. ft.
B.t.u. per cu. ft. gas	500	560
Total B.t.u. in surplus gas ..	3,750,000	5,600,000
Light oil (benzols)	2.6 gal.	5.4 gal.

A comparison in value of by-products on a basis of normal values shows a credit per ton of furnace coke of approximately \$1.25 in favor of the high-volatile coal.

The fourth event was the awakening to the fact that, while an increase in the cubical content of an oven tends to a reduction in plant cost and in operating labor due to handling larger units, a decrease in oven width would more than offset this unit-size advantage because of absolutely different conditions.

The reason for this becomes apparent with an understanding of the factors involved. Increased length of oven gives increased cubical content, and the ultimate economic length depends upon the mechanical and structural limits. Of increased height the same may be said, except that this involves questions of time of contact of volatile products and speed of their flow which modify the advantage and which are yet to be finally worked out.

Increased oven width involves an entirely different consideration. Practically all the heat supplied for the coking of the coal mass flows from the two walls toward the center. This flow of heat depends to a large extent on the resistance and temperature, and in the coke oven the average rate of coking depends, of course, on the rate of heat penetration. The result of this reasoning was the decision, in 1914, to reduce the width of oven from 19¼ in., average then being built, to 18¼ in.

There is no doubt among those who have been acquainted with the wider ovens that the narrower oven has the following distinct advantages:

- 1—Less sponge in the coke.
- 2—Better coke from the same coal.
- 3—As good coke from higher volatile mixtures.
- 4—Higher yields of tar, ammonia, and benzols.
- 5—Low temperatures for the same coking velocity.

The fifth event in coke-oven development is the universal recovery of benzols. The war furnished the primary inducement to developing this phase of the industry; but the fact that the material might be disposed of advantageously for motor fuel after the demand for explosives would cease had an important bearing in stabilizing the large investments demanded.

Previous to the war comparatively few plants were equipped for benzol recovery; in fact, outside the plants of the Semet Solvay Company, operated for their own account, there was comparatively little benzol extracted, and this was used, for the most part, in enriching illuminating gas. To-day practically every coke-oven plant in America has installed this recovery, and the production in 1917 will be in excess of 40,000,000 gal., rated as light oil, if continued at the present rate.

While the removal of benzol reduces the heat units in the gas, the loss in this manner is a very small factor, and the return to be secured from the sale of this product is likely to be greater than that secured from the recovery of tar.

One feature of the benzol credit as related to motor fuel is the smallest of the quantity compared with gasoline production, and, since benzol and gasoline are miscible, the utility of benzol will be enhanced by increasing the quantities available.

In connection with the value of benzol as a motor fuel there is an interesting fact which may in the future have a very marked influence. In many quarters alcohol is looked upon as the ultimate fuel, but it cannot be employed except with less efficiency and with greater difficulties, due to its high hydrogen content. Commercial alcohol and gasoline are not miscible. Alcohol and benzol are miscible and make a most efficient fuel, and, further, after the addition of benzol to alcohol the mixture will carry quite a high proportion of gasoline. The future may see benzol as the tie between gasoline and alcohol, permitting a piecing-out of the gasoline supply and an introduction of alcohol as a commercial motor fuel.

Taking up in somewhat more detail the study of by-product coke and its use in blast furnaces, the phenomenal growth of the by-product industry has stimulated a renewed interest in the main product. This interest is due, first, to the recent revolutionizing of ideas regarding the relative values of by-product and beehive coke. The tardy recognition of the fact that by-product coke of a fairly wide range of origin, when properly used in the blast furnace, gives results not

merely as good as, but much superior to, those obtained from beehive coke, was accompanied by a realization that the limit of efficiency had by no means been reached; that Gruener's "ideal performance"—long the ne plus ultra of blast-furnace men—was actually being surpassed by many blast furnaces, and that much regarding the question of coke economy still remained to be learned. In the renewed study of the subject that this realization is just beginning to stimulate, we have the inestimable advantage that the by-product coke plants are being located in proximity to, and usually under the same management as, the blast furnaces that they are intended to supply, instead of at the coal mines as was the case with the beehive ovens. Thus the blast-furnace operator knows better the sources of the material that he has to

use and the conditions under which it was produced, while the coke-plant operator can more intelligently regulate the performance of his ovens and the quality of his product, according to the requirements of the furnace. Above all, the combination and cooperation of the two plants result in a regularity of performance that is perhaps more to be desired than any specific quality of material. It is to be hoped that this cooperation may soon be extended to the foundry and other industries using coke as fuel.

Abstract of paper presented at a joint meeting of The Franklin Institute and the Philadelphia section of the American Society of Mechanical Engineers, by C. J. Ramsburg and F. W. Sperr, Jr.

RECENT PATENTS

Copies of any one of the following patents can be obtained by sending fifteen cents in stamps to E. G. Siggers, patent lawyer, suite No. 31, National Union Bldg., Washington, D. C., by mentioning THE BLAST FURNACE AND STEEL PLANT:

David Kauffman, Sr., of Pottstown, Pa., has invented improvements in puddle-billet rolling and finishing mill, No. 1,229,283, dated June 12, 1917. The invention is a puddle billet rolling and finishing mill. In the art of rolling or finishing puddle iron, it has heretofore been necessary to utilize many and separate different operations between the puddle ball and the best bar iron. The iron having been formed in balls and worked under the hammer contains considerable slag and it is usually passed through a train of rollers to further expel the slag and also to cause the fibers of the iron to lie on one direction, which gives it malleability. The usual form of trains for the rolling of the iron after it has come from the hammer is that of two rollers arranged vertically to pass the billet in a horizontal direction between the rolls. In order to complete the puddle ball and the finished product, it is necessary to use several kinds of rolling mills, the first set, which may be called the forge train, muck train or puddle bar train, the second or merchant bar train, plate mill, rail mill or wire mill and the third is usually a finishing train. This requires no less than two separate and distinct mills for finishing the bar for commercial use. In the operation of these mills, there may be employed some ten men to each one of the mills, which makes for a high labor cost in addition to the cost of preparing the original mass of "ball" or puddle iron.

Norbert Metz, of Dudelingen, Luxemburg has invented improvements in art of rolling No. 1,229,497, dated June 12, 1917. The invention relates to a universal rolling mill which enables the complete rolling of I-beams by means of one single set of rolls arranged in one single frame and consisting of two horizontal and two vertical rolls. With the said two horizontal rolls four ring-shaped auxiliary rolls are connected which when laterally displaced project into circular grooves or recesses in the front faces of the vertical rolls. In this manner (1) the web faces, and the edges of the flanges can be operated upon when all the four auxiliary rolls join the horizontal rolls; (2) the web faces and the interior and exterior faces of the flanges can be operated upon when all the four auxiliary rolls are separated from the horizontal rolls.

Dwight S. Marfield, of Cincinnati, Ohio, assignor to the Buckeye Products Company, of Cincinnati, Ohio, a Corporation of Ohio, has invented improvements in metal-melting furnaces, No. 1,129,494 dated June 12, 1917. The invention relates to improvements in furnaces for melting metal to be cast. One of its objects is to provide an improved form of rotatably mounted furnace with improved features of assembly. Another object is to provide an improved form of furnace adapted to attain reverberatory effects, and to conserve the heat, and to enable liquid or gaseous fuels to be employed to advantage.

Robert B. Kernohan and Norman C. Rendleman, of Pittsburgh, Pa., have invented improvements in universal mills, No. 1,228,782, dated June 5, 1917. This invention described herein relates to mills for rolling, by the universal process, I-sections I-beams, and like flanged sections, and has particularly to do with mills wherein the rolling is principally effected by two sets and types of rolls one known as the universal rolls, and the other as the edging rolls. The universal rolls, as is well known, comprise a pair of horizontal and a pair of vertical rods having their several axes arranged in substantially a common plane, the horizontal rolls operating upon the web and inner flange surfaces of a blank, and the vertical rolls upon the outer faces of the flanges. The edging rolls comprise essentially a pair of horizontal rolls which operate upon the opposite edges of both flanges, and may be of various specific constructions.

The usual practice in mills of this sort is to arrange the universal and edging rolls in line with each other, that is in tandem, so that the blanks at each pass must necessarily pass through each set at each pass, or in such a manner that a single edging pass may be given without passing the blank twice through the edging rolls. The objection to such an arrangement is that the best results, as far as the product and mill efficiency is concerned may not always be obtained by a substantially equal number of edging and universal roll passes, or by invariably alternating such passes, or by passing the blank through the edging rolls twice where but a single operative pass is desirable. Furthermore, when the arrangement of rolls is such that an edging pass may not be effected without a simultaneous universal pass, the blank is partially dragged through the edging rolls, which consequently become worn very rapidly and must be frequently turned down.

Friedrich Schaffer of Loebersdorf, Austria has invented improvements in method of making car wheels No. 1,227,962, dated May 29, 1917. The so-called disk-wheels, such as are used on railway-cars are made according to the known methods in one piece from one solid block of steel. Whenever such a disk-wheel is subjected to a treatment by heat, such as is suitable for the particular alloy of steel and which is intended to improve the material, the said wheel will be found in the course of such treatment to undergo stresses of a highly disadvantageous nature which will eventually result in the destruction of the wheel. The process of first heating and then suddenly cooling down (quenching in water, oil, etc.) the material constitutes either a part or the whole of the treatment by heat. The disk portion of the wheel, being a comparatively thin metal portion and having a large cooling surface, will during the quenching period first cool off and simultaneously shrink, while the tire of the wheel and the hub, representing large masses of metal will much more slowly cool down and shrink.

Charles W. Hawthorn, of Hamilton, Ontario, Canada, invented improvement in rolling mills, No. 1,228,433, dated June 5, 1917. This invention relates to a process and apparatus for rolling metal bars and shapes,

NEWS OF THE PLANTS

The Jackson Fire Brick Company, Jackson, Tenn., has purchased the plant and business of the Hunt Pressed Brick Company, successors to the Southern Tile & Brick Works, Jackson, Tenn., makers of fire clay brick.

A new company to be known as the Frederick Iron & Steel Company, has been formed by W. A. Riddell, Hugh H. Obear, and Charles McC. Mathias. The new company has purchased the entire property of the Morris Iron & Steel Company, Frederick, Md., through Mr. Riddell.

The Booth Hall Company has been formed to conduct an electric furnace building, engineering and metallurgical business, with offices at 565 West Washington Boulevard, Chicago, Ill. The Company has applied for patents on an electric furnace, which will be designed in three different types, to suit the metallurgical conditions of the individual customer and to operate either one, two, or three phase.

The Cambria Steel Company, Johnstown, Pa., has put into operation No. 10 blast furnace, a duplicate of Nos. 7, 8 and 9 stacks. The stack has a rated capacity of 500 tons a day.

The National Castings Company, Marietta, Pa., will commence operations in its new foundry on July 2. Gray iron and semi-steel castings will be produced.

Outstanding bonds of the Youngstown Iron & Steel Company, Youngstown, O., recently acquired by the Sharon Steel Hoop Company, Sharon, Pa., will be retired July 1.

The Pennsylvania Engineering Company, New Castle, Pa., recently has increased its capital from \$600,000 to \$1,000,000. Stock dividends aggregating \$300,000 will be distributed July 1, the remainder to be retained in the treasury.

The Washington Mold, Foundry & Machine Company, Washington, Pa., has commenced operations in the remodeled plant of the Crescent Glass Company. Officers of the company are: J. L. Scheli, president; W. J. Bromley, vice president; C. M. Bromley, secretary, and Charles Bromley, treasurer.

J. D. Dockendorff & Company, 20 Broad street, New York, export and import merchant, representing steel mills and manufacturers of kindred lines for export, recently has been incorporated with \$500,000 capital. Officers of the company are: J. E. Dockendorff, president; V. J. Sudman, secretary and treasurer; F. Lagerholm, assistant secretary and G. M. Hasbrouck, assistant treasurer.

The Superior Steel Company, with works at Carnegie, Pa., has removed its general offices from that city to the Union Arcade building, Pittsburgh. C. H. Forster, who was recently appointed secretary and treasurer of the Superior corporation, formerly was connected with the American Iron & Steel Manufacturing Company, Bethlehem Steel Corporation.

The twenty ninth annual convention of the American Boiler Makers Association was held at the William Penn Hotel, Pittsburgh, Pa., June 25th. Thomas E. Durban, chair-

man of the American Uniform Boiler Law Society, spoke on the subject of "Boiler Manufacture in the War." George A. Luck, representing the Massachusetts Board of Boiler Rules spoke on steam boiler regulation in that state. C. V. Kellogg Vice President of the association spoke on "The By-Products of the War."

The Bethlehem Steel Company is dismantling the iron ore roaster at its Colebrook plant at Lebanon, Pa.

The increase in business and the need for greater floor space and facilities for displaying Johns-Manville products, necessitated a change in location of the H. W. Johns-Manville Company at Pittsburgh on May 20th.

On this date, new and larger Johns-Manville Showrooms and Sales Offices were opened on the ground floor of the Westinghouse Building, corner of Ninth street and Penn Avenue.

These new quarters provide ample space to accommodate the increasing business, and are located in the heart of Pittsburgh's business district, within a few minutes' walk from the Union Station.

A new six story unit is being added to the Milwaukee Works of the Cutler-Hammer Manufacturing Company, makers of C-H Motor Control Apparatus, Push Sockets, Switches and other Electrical Products. The new building, work on which has progressed as far as the fourth floor, is of fire-proof reinforced concrete construction. The four lower floors of this first unit will be turned over to manufacturing, stock rooms and testing rooms, while the two upper floors will be devoted to office purposes.

The Brier Hill Steel Company, Youngstown, O., has awarded a contract for a 110 inch plate mill and auxiliary equipment to the United Engineering & Foundry Company, Pittsburgh.

The Blaw-Knox Company is the new name of the corporation succeeding the Blaw Steel Construction Company, Pittsburgh, fabricator of shapes and transmission towers, with plant at Hoboken, Pa., and the Knox Pressed & Welded Steel Company plant, Wheatland, Pa., manufacturer of open hearth furnace accessories. The capital of the company will be \$2,000,000. Present officers of the Blaw company retain their titles, and the board will be increased to take in five directors of the Knox Company. The general sales offices of the company will remain in Pittsburgh with branch offices as heretofore. The executive offices will be at Hoboken.

The Mark Manufacturing Company, Evanston and Chicago, which is building a large steel works at Indiana Harbor, has increased its capital from \$10,000,000 to \$25,000,000 under its Delaware charter.

The Freyn and Company of the State of Maine has recently been organized, with an authorized capital stock of \$175,000. This corporation is the successor of Heinrich J. Freyn Inc., and will continue to do the contracting and engineering of the former concern, particularly in the iron and steel industry. The officers of the company are, Heinrich

J. Freyn, President, and C. D. Rawstorne, Secretary, with offices at 643 Peoples Gas Building, Chicago, Ill.

Shipments of steel from the Pittsburgh district for use by the government during May aggregated 69,112,141 tons, according to reports received by the Bureau of Construction and Repair of the Navy Department. The Carnegie Steel Company shipped 63,542,930 of the amount and other companies the balance.

The Refractory Magnesite Corp., a New Jersey corporation, capital \$100,000, will mine manganese ores, copper ores, etc. The incorporators are: A. W. Britton, L. H. Gunther and Joseph F. Curtin.

Contracts have been placed by the Youngstown Sheet & Tube Company, for the construction of an 84-inch tandem type motor-driven plate mill which will have a capacity of from 12,000 to 15,000 tons per month. The output will be used principally for the manufacture of large size of lap weld pipe which requires skelp from 45 inches to 72 inches in width.

The unit will include four continuous furnaces, and will be housed in connected buildings of five sections including slab building, 80 x 140 feet, motor building, 80 x 140 feet, conveyor building 80 x 540 feet, shipping building 80 x 280 feet. The buildings will be of structural steel with corrugated iron roofing and siding, except the motor building, which will be of brick construction with composition roofs. The Blaw-Knox Company will erect the structural steel; the

Mesta Machine Company, the mill and tables; Hilles & Jones, Wilmington, Del., the shears and levels; the Allis-Chalmers Company, the larger motors; the General Electric Company, the smaller motors. The cooling table will be erected by Hyle & Patterson, and the furnaces by Alex. Laughlin. The order has not yet been placed. It is expected that the new unit will be in operation within 12 months.

The company's new 12-inch bar mill is completed and will be in operation soon. This mill and the 9-inch bar mill started several weeks ago will have a capacity of about 16,000 tons per month.

In addition to subscribing \$25,000,000 more to the Liberty Loan bonds, bringing its total subscription up to \$50,000,000, the United States Steel Corporation has declared an extra dividend of 1 per cent on the common stock to enable stockholders, should they so desire, to contribute to the \$100,000,000 fund which is being raised by the American National Red Cross for army purposes. If all the steel Corporation's common stockholders contributed their 1 per cent dividend the Red Cross realized about \$5,500,000.

During a recent storm in Youngstown one of the ore bridges of the Youngstown Sheet & Tube Company was completely destroyed by being blown over. The operator was killed in the accident.

C. T. Griswold, geologist of the Associated Geological Engineers of New York, has gone to Wyoming.

INDUSTRIAL SAFETY

In its campaign for the improvement of conditions affecting the health of persons employed in the metallurgical industries, the Bureau of Mines, Department of the Interior, in cooperation with the Public Health Service, has issued a report on carbon monoxide poisoning in the steel industry, setting forth the liability to carbon monoxide poisoning of those employed in the various departments of a steel plant, the source of the gas, the extent to which it is present, its effects on workers, and makes recommendations for the prevention and remedy of such conditions.

Attention is given primarily to the liability to chronic poisoning—that is, the daily exposure of employes to small quantities of this gas over an extended period of time—rather than to that of acute poisoning, or "gassing," as prevention of this accident is a problem of safety engineering rather than of industrial hygiene. Rapid and serious poisoning rarely occurs except where the atmosphere is suddenly and grossly polluted with gas because of a breakdown or because of faulty operation of machinery. Such conditions are usually unforeseen, soon discovered, and quickly corrected. It is the purpose of this paper to call attention to the effects of the continued presence of small quantities of this gas, which, although insufficient to cause acute symptoms of intoxication, will nevertheless by insidious action finally bring about the same result—that is, total or partial incapacitation of the worker.

From the viewpoint of the physician interested in occupational diseases, or of the industrial hygienist, carbon monoxide is the most important of the poisonous gases. This gas occurs so frequently as either a product or a byproduct of many industrial processes that those employed in or

around such processes may be, and often are, exposed to its action. The presence of this gas in a place where men are at work, even though it be confined to the interior of manufacturing appliances and equipment, is a hazard, for experience has taught the difficulty of preventing leaks and the serious and rapid results that follow inhalation.

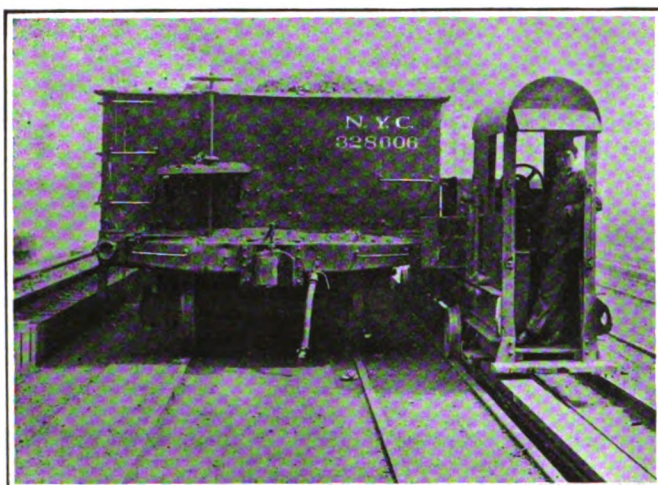
In no industry have such changeable conditions been more marked than in the steel industry. For example, the gas from blast furnaces was formerly allowed to escape as a waste product; it is now collected and utilized in the production of steam and motive power. The increasing use of gas as a fuel at steel plants, as in open hearth furnaces, has led to its extensive manufacture in gas producers. Thus another source of carbon monoxide has been added. In addition, new processes of manufacture offer the hazard of carbon monoxide poisoning. For example, industrial advancement has created a demand for many grades and qualities of steel and this has led to the use of special furnaces. Also, there arose a large demand for refractory materials for use throughout steel plants and among other hazardous processes, the preparation of dolomite for such use appeared. Another industrial change of equal hygienic importance was the gradual substitution, especially in the steel industry, of the gas engine for the steam engine. In a modern steel plant one sees large buildings housing many engines which utilize gas having a large content of carbon monoxide. This use involves certain hazards to those concerned in transmission of the gas from the blast furnaces and its utilization at the engines. Not in steel making alone but in nearly all industries the hazard of carbon monoxide poisoning is increasing with the general technical advancement of industry.

WITH THE EQUIPMENT MANUFACTURERS

PUSHER CAR.

The Erie Dock Company, of Cleveland, is using on their docks the Brownhoist Patented Car Pusher, as shown in the illustration. These machines are used in connection with the ore unloaders and they eliminate the necessity of keeping a switch engine on the docks for shifting the cars. The unloaders span 3 railroad tracks and between each set of tracks are located the rails in which the Brownhoist Car Pushers travel. Each machine handles cars on both sides.

The machine consists of a rigid frame supported on 4 single flange track wheels operating on 3-ft. 5½-in. gage track. There are two differential drums mounted on the frame and these drums are geared to a 40 horsepower motor,



220 D. C. A powerful brake is located on the motor armature shaft.

As shown in the illustration, there is a broad steel arm located at the front end of the cab, which can be thrust out to either side of the machine. This is accomplished by means of a hand wheel located in the cab. When this steel arm is thrust out, it is in right position to strike the end sill of the railroad car. And by traveling, the machine pushes the cars along the track.

The car pusher is propelled by means of a single cable. This cable runs between the rails the full length of the dock 425 feet. It is securely anchored to concrete foundations at both ends through a spring tension device which keeps the cable taut. This line runs round the two drums on the car pusher and by starting the motor the machine is propelled along the track. The travelling is reversed by reversing the motor. Each machine produces a draw-bar pull of 8000 pounds with a speed of 100 ft. per minute. Power is obtained from two lines of conductor bars running between the rails and these bars are guarded with a wooden covering.

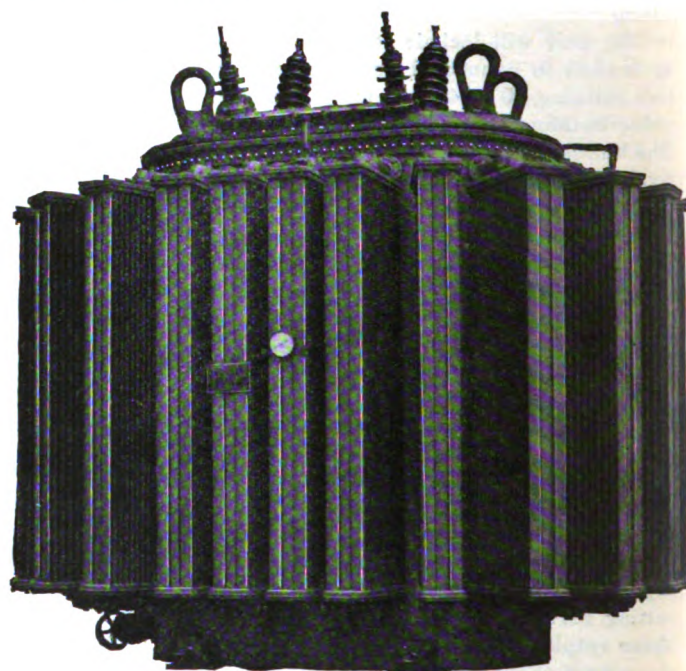
The car pusher is 26 ft. over all and has a wheel base of 16½ ft. When operating between railroad tracks laid in 14 ft. centers, there is a clearance of 5-in. between the car pusher and the largest steel hopper cars.

These pushers were operated during the season of 1916 and were found to be a big item in speeding up the unloading of boats as dispensing with the continuous use of a switch engine.

WORLD'S LARGEST SELF-COOLED TRANSFORMERS

The General Electric Company, of Schenectady, N. Y., has built six of the largest self-cooled transformers in the world, aggregating 48,000 Kv-a for the Carnegie Steel Company. They are single-phase, 25 cycle, 8,000 Kv-a each and step the voltage from 44,000 volts to 6,600 volts.

A unique feature of these transformers is the construction of 24 radiators external to the containing tank, giving a radiating surface approximating one million square inches. Cooling is obtained by an automatic circulation of oil through the radiators. All of the principles and characteristics of the "Circular Coil Type H" design with the circular disc coil interleaved windings and three-legged core were incorporated in the construction.



Outdoor Transformer Radiator Tank.

The radiating units consist of vertical flattened tubes rigidly welded into headers which are flanged for bolting to the tanks. The cast iron elbow between the tank and the radiator is provided with a machined surface where it is bolted to the flanges of the tank and the radiator. The absence of any screwed pipe fittings, assures an oil tight joint.

All seams and joints in the tank and radiators are welded to prevent oil leakage. None are soldered, brazed or riveted. The radiators are self-draining and have no pockets, preventing the accumulation of air at the top or of moisture and sediment at the bottom. These refinements of the "radiator" type of transformer, originated by the General Electric Company, have materially increased the Kv-a rating of self-cooled transformers and make possible a wider latitude in their field of application.

The Combustion Engineering Company of New York, has issued a New Catalog containing information concerning recent installations of Type "E" Stockers, with various types of boilers. A number of large units are illustrated.